Annex IV - Methodology and Models Used

Contents

IV.1 Methodology

This note describes the data sources and methodology used to estimate the percentage impacts on GDP of the MBM scenarios. The total estimated impact on GDP is calculated as the sum of the impact via air transport (both from passengers and freight) and the impact via maritime shipping. The methodology for calculating estimates of the impacts from each of these components is described in the remainder of this note.

IV.1.1 Policy assumptions and sensitivity analysis

One of the crucial issues is to decide which levels of levy should be modelled. We have analysed previous studies. IMO's MBM Expert Group worked with two sets of carbon prices (in current dollars), medium and high. Prices increased over time, starting at USD 20 in 2010 and increasing to USD 40 (medium) or USD 100 (high) in 2030 (MEPC 61/INF.2). Anger et al. (2009) used constant carbon prices (in 2015US$) and four different price levels for a levy, ranging from USD 2.4 per tonne of CO2 to USD 14.2 per tonne of CO2. Faber et al. (2010) used three, constant carbon prices, ranging from USD 10 per tonne of CO2 to USD 50 per tonne of CO2. For this study, we propose to use carbon prices of USD 25, 50 and 75 per tonne of CO2, constant over time and in 2015US$. These prices reflect the range of carbon prices in the other studies. We propose to use constant prices for reasons of transparency and ease of modelling.

For ETS schemes, E3MG can model the resulting carbon price. Using an endogenous carbon price is the correct approach because under emissions trading the quantity of emissions allowed is fixed and the market price has to adjust accordingly. However, when systems have unlimited access to offsets, we should consider using an exogenous carbon price for comparison purposes.

Therefore we have used the following policy assumptions:

- MBM(s) will be implemented in 2015 (the EU ETS for aviation that began in 2012 is an exception here)
- base year is 2007
- cap set at 2007 level for the period 2015-2025
- MBM impacts will be reported for the years 2015 and 2025 or for the whole 21-year period where possible
- to allow for sensitivity analysis we propose to use three levels of levy: USD 25, 50 and 75 per tonne of CO2 in 2015US$
- to allow for sensitivity analysis we propose to use two levels of auctioning in emissions trading schemes - 15% (as in the current EU ETS) and 100%

In addition to fuel price scenarios the study has taken the EEDI into account as has been decided at MEPC 62 (RESOLUTION MEPC.203(62)). For reasons of transparency and ease of modelling, we have assumed that the waiver would not be used.

IV.1.2 Mapping of status quo and counterfactuals

After approval of CSEs a baseline scenario for each of the CSE economies in which a path of economic development has been set (as a result of analysing the E3MG results, available data and subsequent discussions between the team and CSEs governments, steering group and other stakeholders) up to 2025 but in which there are no MBMs for international transport. (See Annex 1)
We have as much as possible (based on available literature) considered the costs of non-action in the baseline scenarios.

For all large developing countries and globally, baseline projections of GDP and population are available within E3MG and we have used these as counterfactuals.

Smaller developing countries, e.g. SIDS, are not covered separately in the E3MG model. For these countries, a more detailed analysis of the baseline scenario has been done. Such an analysis includes:

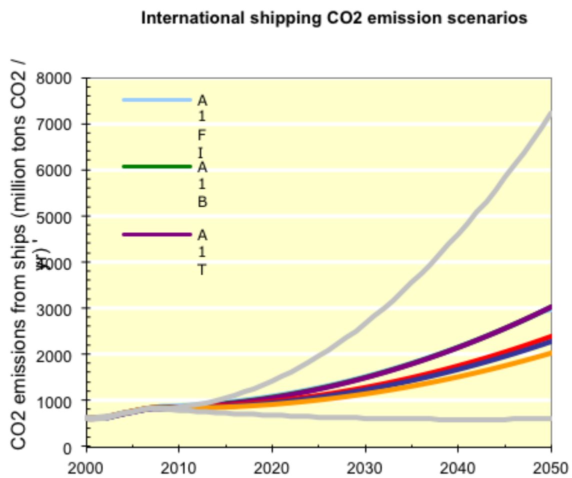
- Analysis of the economic development of the region a country is in, based on E3MG modelling projections.
- Analysis of major trades. Special attention will be paid to exports of ores and coal, and agricultural products (e.g., edible oils, rice). The former may change over time as a result of depletion of resources, while the latter may be affected by changes in productivity and demand. Imports can in many cases be expected to be a function of GDP.
- Plans for port expansions, impacts of the expanded Panama Canal, and other changes of shipping routes. Larger ports may enable larger ships to access the country, significantly lowering the per unit freight rate.
- Additional ad-hoc analyses as required.

IV.1.3 Establishing a baseline scenario for international shipping and aviation

This study concerns CO2 emissions from international aviation and shipping only. Therefore we assume that domestic emissions from aviation and shipping are covered by national policies and will be **not modelled** as a part of this study.

This study adopts a baseline scenario for international shipping CO_2 emissions based on the Second IMO GHG study 2009 (MEPC 59/INF.10 Chapter 7) A1B scenario (Figure below). The baseline scenario reflects projected business as usual international shipping emissions. Scenario A2 was chosen as it represents one of the middle scenarios of the international shipping emissions.

Figure IV. 1 **Trajectories of the emissions from international shipping. Columns on the right-hand side indicate the range of results for the scenarios within individual scenario families.**



Source: MEPC 59/INF.10 p. 134.

Scenarios in the Second IMO GHG Study 2009 are based on the framework for global development and storylines that have been developed by the Intergovernmental Panel on Climate Change (IPCC) in the Special Report on Emission Scenarios (SRES), and are named according to IPCC SRES terminology. Scenario SRES A2 was chosen as it represents one of the middle scenarios for international shipping emissions.

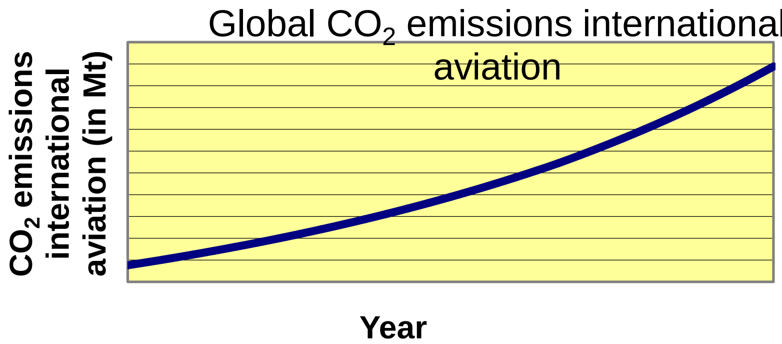
For international aviation we propose to use the CAEP8 Medium Growth scenario. This scenario is specified in terms of an annual growth of passenger km for 23 route groups for the periods 2006-2016, 2016-2026 and 2026-2036 (Table below). Figure below presents CO2 emissions from international aviation as projected by the CAEP8 Medium Growth scenario.

Table IV.1 Overview of the growth percentages in the CAEP8 Medium Growth scenario. Source: CAEP- SG/20082-IP/02, table 3.

Sector / Route Groups	2006 -2016	2016 -2026	2026 -2036	2006 -2026	2006 -2036
International			[% growth]		
1. North Atlantic	4.8	4.3	3.8	4.5	4.2
2. South Atlantic	5.8	5.6	5.3	5.7	5.6
3. Mid Atlantic	5.8	5.3	4.8	5.5	5.2
4. Transpacific	6.4	5.6	4.9	6.0	5.6
5. Europe ←→ Asia/Pacific	5.8	5.3	4.8	5.5	5.2
6. Europe ←→ Africa	5.5	5.5	5.5	5.5	5.5
7. Europe ←→ Middle East	6.4	5.6	4.9	6.0	5.6
8. North America ←→ South America	5.4	4.6	3.9	5.0	4.6
9. North America ←→ Central America and Caribbean	4.7	4.7	4.7	4.7	4.7
10. Middle East ←→ Asia / Pacific	6.5	5.7	5.0	6.1	5.7
11. Intra Africa	6.0	6.0	6.0	6.0	6.0
12. Intra Asia/Pacific	6.3	5.8	5.3	6.0	5.7
13. Intra Europe	4.3	3.8	3.3	4.0	3.7
14. Intra Latin America	6.0	6.0	6.0	6.0	6.0
15. Intra Middle East	5.8	5.3	4.8	5.5	5.2
16. Intra North America	3.8	3.3	2.8	3.5	3.2
17. Other International Routes	5.2	5.2	5.2	5.2	5.2
Total International	**5.4**	**5.0**	**4.6**	**5.2**	**5.0**
Domestic					
18. Africa	5.8	5.6	5.3	5.7	5.6
19. Asia/Pacific	7.4	6.6	5.9	7.0	6.6
20. Europe	3.8	3.3	2.8	3.5	3.2
21. Latin America	6.1	5.9	5.6	6.0	5.9
22. Middle East	4.6	4.4	4.1	4.5	4.4
23. North America	3.0	2.5	2.0	2.7	2.4
Total Domestic	**4.5**	**4.3**	**4.1**	**4.4**	**4.3**
Global [International + Domestic]	**5.1**	**4.8**	**4.4**	**4.9**	**4.8**

[1] Average annual growth rate of revenue passenger-kilometres.

Figure IV.2 Global CO2 emissions of international aviation in the CAEP8 Medium Growth scenario.
Source: CAEP- SG/20082-IP/02 and AERO



IV.2 Models used

IV.2.1 E3MG

4CMR will apply its energy-environment-economy (E3) model at the global level (E3MG[1]) to contribute to the Impact Assessment. The analysis in E3MG provides the global coverage desirable for studying an international industry such as international aviation and shipping. The model covers 20 world regions that include all major developing economies, such as Brazil, Mexico, India and China. The European Union is also represented in E3MG and this allows for studying the impacts of EU unilateral climate policies for international aviation and shipping.

The model has been applied in previous Impact Assessments for the European Commission and the UN and has a theoretical framework characterised by:

- A high level of disaggregation in terms of the sectors of the economy and the categories of final expenditure identified.
- An input-output framework that identifies explicitly the interdependencies between sectors.
- Two-way linkages between the economy and the energy system such that changes in one (e.g. from policies) impact on, and are reflected consistently in, the other.
- Dynamic econometrically-estimated equations, capturing short-term impacts followed by medium-term adjustment to a long-run steady state.

E3MG is based on annual time-series data with a detailed sectoral disaggregation. The main data sources are:

- OECD Structural Analysis database
- International Energy Agency
- Edgar emissions database
- Eurostat
- World Bank
- United Nations

[1] Energy-Environment-Economy Model at the Global level: http://www.e3mgmodel.com/.

The high level of sector disaggregation in the model and its interconnectedness through the input-output framework makes it capable of examining the potentially differing impacts on each sector both directly and indirectly (through changes in demand from other sectors). This economy-wide, as opposed to partial, approach recognises that there may be implications for sectors that are not specifically targeted by a particular policy package and is an important consideration in an Impact Assessment. The integrated treatment of the energy system allows for the analysis of policies that, for example, tax fuels or carbon emissions such as levies on bunker fuels.

The last of the characteristics listed, empirically-validated dynamics (the time path of an economy), is a key feature of E3MG that sets the model apart from the Computable General Equilibrium (CGE) approach. CGE models are 'static' in that they compare depictions of the economy that are in equilibrium before and after a policy intervention; the transition between the two states is not captured in the models[2]. In contrast E3MG does capture such transition (non-equilibrium) states.

Another area in which E3MG differs from many other models is that it does not assume perfectly-competitive markets in which long-run economic profit is impossible. Instead, products may be differentiated and/or firms may be large relative to the size of the market, allowing for price-setting behaviour. This is important when considering impacts on sectoral and regional competitiveness, for example, due to changes in transport prices.

In summary, E3MG is a dynamic input-output model with detailed, fully-consistent treatments of energy demand and the consequent emissions. Such a structure permits the integrated analysis of energy and environmental policies on the economy as well as the effects of economic drivers on energy demand. The model is suitable for the analysis set out in the Invitation to Tender.

However, only China, India and Mexico are separately modelled in the E3MG model. E3MG can therefore not be directly employed for the country case studies for smaller developing countries. Therefore, more generalised data and relationships from the E3MG can be used for ad hoc econometric modelling for smaller developing countries. Thereby the information from the E3MG will be used conjunctively with country specific information. Country specific information will both relate to macroeconomic data and aviation and shipping related data from respectively the AERO and shipping models available for this study.

IV.2.2 Marginal Abatement Cost Curve Model

CE Delft has developed a model for generating marginal abatement cost curves (MACCs) for the shipping sector. The model can calculate MACCs for any combination of major ship types, for several ship sizes. It typically presents a range of MACCs (a high, central and low estimate of both costs and abatement potential). The model is flexible so that different assumptions on costs or abatement potential, as well as different measures can be included in the analysis. It allows for different assumptions on fuel price and discount rates.

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2 Moreover, 'dynamic' CGE models are actually analyses of successive equilibrium states; they do not model the actual adjustment mechanism between states.

The model currently has 22 measures in 15 groups (measures within one group are mutually exclusive). For each measure, it has a low, central and high estimate of costs and abatement potential that is based on a wide range of sources, including data from stakeholders that have implemented the measures.

The model disaggregates fourteen ship types and several size categories, and has 53 combinations of ship type and size. MACCs can be provided for any selection of these ships categories.

IV.2.3 Ship Emission Projection and Freight Cost model

CE Delft, DLR and David Lee have developed a model that projects ship emissions and cost price increases for any region under a wide range of policy scenarios and several allocation options up to 2050.

The model uses base year emission and emissions data (which can be taken from a number of sources – here we propose to use the 2nd IMO GHG Study baseline) as an input, and projects activity levels either based on exogenous inputs (e.g. trade volume projections from an economic model) or on economic projections (e.g. GDP projections).

The model assigns transport demand to ship movements, taking fleet size development projections from the 2nd IMO GHG Study into account.

The model calculates emissions based on ship movements and incorporates efficiency improvements of CE Delft's MACC model.

The model is flexible with regards to assumptions on fuel prices, policy scenarios (EEDI, global or regional carbon prices), discount rates, take-up of cost-effective efficiency improvement measures, maximum abatement potential, et cetera.

IV.2.4 AERO

The AERO model can examine the impacts of different policies intended to reduce international and/or domestic aviation GHG emissions. The model is able to assess the consequences of a wide range of policy measures aimed at reducing aviation emissions (including technological, operational and market based measures), and can produce outputs at all geographical levels (global, regional, country). Policy measures can affect the supply side costs of the industry, which may lead to airlines increasing prices to customers. The AERO model forecasts the extent to which demand for air travel is reduced due to higher prices, and the changes in the structure of the global fleet with respect to fuel efficient technology. The effects of policy options are computed relative to a future scenario, whereby a scenario reflects an expectation of autonomous developments with respect to air transport and flight activities without emission reduction options being imposed. All AERO computations depart from a Base situation representing the air transport system for the Base Year (presently 2006).

The AERO Unified Database includes the EUROCONTROL WISDOM Operations Database which contains a detailed record of aviation movements in the Base Year. For 2006, the Unified Database records 123,025 airport-pairs with 33.1 million civil flights. Airline cost and fare data in the AERO model are based on IATA and ICAO data. The aircraft type input data are based on fleet inventory properties from the EUROCONTROL PRISME Fleet 2, OAG Fleet Databases, ICAO emissions databank and the FESG retirement curves. Finally the specification of aircraft performance characteristics are based on the EUROCONTROL BADA data.

Since 1995, the AERO model has formed a key part of over 20 international studies for various organizations (e.g. ICAO, IATA, EC, and UNFCCC) where the results have provided a quantified basis for policy judgment related to the reduction of GHG emissions. Recently (2011) the model was employed for an impact assessment of MBMs for ICAO.

For this study the AERO model will be used to assess the impacts of MBMs for developing countries. For any MBM, the AERO model can output effects for individual countries and country groups (AERO considers 14 world regions). The most important AERO computed impacts for this study relate to:

- Passengers and freight demand;
- Aircraft movements;
- Passenger fares and freight rates;
- Airline cost and revenues; and
- Fuel use and GHG emissions.

As part of the study an interface will be established between the AERO model and the E3MG model whereby the 20 world regions in E3MG will be mapped to the 14 world regions considered in AERO.

The ownership of the AERO model is with EASA. TAKS BV (being subcontracted by CE Delft for this study) has a Licensing Agreement with EASA for the use of AERO for various studies. Through the Licensing Agreement EASA has access to the results of AERO model runs.

Also for this study EASA has indicated they intend to grant permission for the use of AERO through the Licensing Agreement. Before the AERO model is employed for this study, it has to be ensured that the terms of conditions in the Licensing Agreement with EASA are not in conflict with the General Conditions for the contact of the Consortium with DFID.

IV.3 Ad Hoc modeling

This note describes the data sources and methodology used to estimate the percentage impacts on GDP of the MBM scenarios. The total estimated impact on GDP is calculated as the sum of the impact via air transport (both from passengers and freight) and the impact via maritime shipping. The methodology for calculating estimates of the impacts from each of these components is described in the remainder of this note. This methodology takes into account only direct impacts and the feedback effects, for example from raise in outputs of domestic industries as a response to increased import prices, and multiplier effects, for example the impacts of decreases in tourist expenditure on activity in domestic industries that support tourism activities, are not accounted for. The MBM impacts on other countries apart from a particular CSE of interest do not impact the CSE in this modelling exercise that is in reality unlikely if the MBM is global. Also the ad-hoc methodology assumes that the current trends in CSEs economies are going to continue up to 2025 and the shares of export, import and tourist expenditure in CSEs GDPs are going to remain the same as in 2011 (or 2010 in some cases). This is a strong assumption as the world trade has been shown to be volatile (COMTRADE, 2012). In addition, the study assumes that there are no adjustments to trade values from changes in currency exchange rates.

Air Transport

Data

The primary inputs to this analysis are national accounts aggregates from the United Nations Statistics Division and the estimates of direct impacts on aviation revenues and volumes from the AERO model. The table below outlines the sources of all the data inputs.

Data Input	Source
Impact on airline revenues (US$ per tonne-km % change)	AERO model
Impact on aviation cargo volumes (000s tonnes, % change)	AERO model
Impact on aviation passenger volumes (000s passengers, % change	AERO model
Aviation revenues raised (current price US$)	AERO model
Exports of goods & services (current price US$)	UNSD, National Accounts Estimates of Main Aggregates
Imports of goods & services (current price US$)	UNSD, National Accounts Estimates of Main Aggregates
GDP (current price US$)	UNSD, National Accounts Estimates of Main Aggregate
International tourism receipts, net of transport costs (current price US$)	World Bank
Cost of freight in total value of imports (%)	Hummels et al (2009)
Proportion of total freight carried by aviation (%)	Assumption, based on calculations from COMTRADE Data
Proportion of total tourist arrivals carried by aviation (%)	Assumption, based on calculations from COMTRADE Data

In order to translate the increase in aviation costs into an increase in import prices it is necessary to use an estimate of the proportion of aviation costs in total import value. Here we use values estimated by Hummels et al (2009) for Chile and an average of those estimated by Hummels et al (2009) across eight Latin American countries for the remaining Case Study economies[3]. It should be noted that these estimates refer to all transport modes and are not specifically disaggregated by maritime or aviation freight.

Additionally it is necessary to make an assumption about the proportion of total freight carried by aviation and the proportion of total international tourism carried

[3] An attempt was made to estimate country-specific freight costs using the matched partner methodology. However the ComTrade series of imports and exports for the case study economies and their trading partners were found to imply implausible values of transportation and insurance costs. The fact that the matched partner methodology is subject to substantial measurement error is documented in the academic literature (Hummels 2009).

by aviation. These numbers are based on authors calculations from COMTADE data (imported/exported goods by value) and vary by country.

Data Processing

In the case of the Cook Islands, it was not possible to obtain international tourism expenditure data from the World Bank. Instead, estimates for the average tourism expenditure per visit in 2006-07 were obtained from the Cook Islands Tourism Visitor Satisfaction & Impact Monitor (NZ Tourism Research Institute, 2007). This was multiplied by the total visitor arrivals series from the Cook Islands Statistics Office to infer estimates of total annual tourism expenditure.

The last year of historical data for the economic times series is 2010. In order to estimate policy impacts for the year 2025 it has therefore been necessary to project the time series forward. This has been done using customised software algorithms which project the times series forwards on the basis of historical trends. Note however that given the purpose of this exercise is to estimate the percentage impacts of the policy scenarios, it is the shares of the time series in total GDP, rather than the absolute levels, that is important for the analysis.

Methodology

1) Freight

Figure 1 summarises the methodology used to estimate the percentage impact, attributable to freight of the policy scenarios on GDP. The first stage of the process is to use the AERO model outputs to calculate the percentage change in import prices. The percentage increase in airline revenues per tonne-km from the AERO model is taken to be an estimate of the increase in unit freight costs. This is then weighted by the share of freight in the total value of imports and the proportion of total freight carried by aviation to yield an estimate of the percentage change in import prices.

The percentage change in consumer prices is then calculated as the percentage change in import prices weighted by the share of imports in total domestic consumption. This is calculated using the UNSD estimates of the main national accounts aggregates. Domestic prices are assumed to remain unchanged. This increase in consumer prices represents the percentage reduction in real income and is therefore inversely proportional to the reduction in consumption.

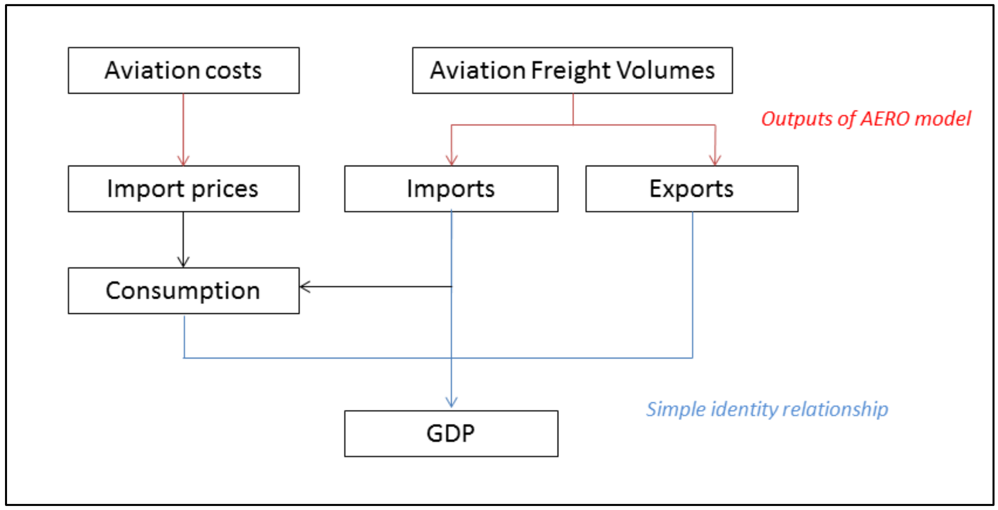
The percentage change in import and export volumes is taken to be equal to the estimated percentage impact on total cargo volumes (000s tonnes) from the AERO model (measured on an arrivals and departures basis, respectively). A further change in import volumes is calculated as the percentage change in consumption weighted by the share of imports in total domestic consumption. The aggregate percentage impact on GDP is then calculated by accounting identity i.e. as the percentage change in imports, exports and consumption weighted by their shares in GDP.

It should be noted that a positive net impact on GDP may arise where:

- the share of imports in GDP is large relative to the share of exports; and/or
- the percentage change in cargo from imports is greater than or close to the percentage change in cargo for exports.

This can result in the negative impact of a reduction in exports being outweighed by the reduction in imports, which by accounting identity has a positive impact on GDP.

Figure 1: Summary of Aviation Methodology



2) Passengers

A reduction in airline passenger volumes is hypothesised to primarily effect the GDP of the case-study economies via a reduction tourism-related economic activity. The starting point for estimating this impact is the percentage change in total airline passengers (000s passengers) from the AERO model. The reduction in tourists' expenditure is assumed to be proportionate to this reduction in tourist volumes. This is multiplied by the proportion of international tourists carried by aviation and the share of international tourist expenditures in GDP to obtain the percentage impact on GDP itself. An additional impact on GDP is also calculated in the form of the impact of a reduction in tourism expenditure on imports. The is calculated as the percentage change in tourism expenditure weighted by the share of tourism expenditure in total domestic consumption and the share of imports in total domestic consumption. Multiplying this by the share of imports in GDP gives the percentage impact on GDP arising through the effect of a reduction in tourism expenditure on import demand.

3) Revenue Recycling

The impact of revenue recycling is represented in the framework as an increase in total domestic consumption in each of the case study economies. The revenues raised are provided as inputs to the analysis from the AERO model. These revenues are then adjusted to reflect the share of free-allowances and/or carbon price in each of the scenarios. The percentage impact on GDP arising from revenue recycling is then calculated as the percentage increase in total domestic consumption as a result of the revenues weighted by the share of total domestic consumption in GDP.

4) Total

The total percentage impact of each policy scenario on GDP is the sum of the percentage impact attributable to freight, the percentage impact attributable to passenger transport and the percentage impact attributable to revenue recycling, There are a number of caveats to the analysis relating to the availability of sufficiently detailed data. When calculating the shares of imports and exports in GDP and the share of imports in total domestic consumption, both goods and services are included. In reality only manufactured goods are likely to be internationally traded by these case study economies.

Maritime Transport

Data

The primary inputs to this analysis are national accounts aggregates from the United Nations Statistics Division, import and exports carried by sea from Eurostat and the estimates of direct impacts on maritime freight costs from the CE Delft shipping model. The table below outlines the sources of all the data inputs.

Data Input	Source
Impact on maritime transport costs (% change)	CE Delft shipping model
Price Elasticity of maritime freight transport	CE Delft shipping model
Maritime revenues raised (current price US$)	Authors calculations based on shares of trade volumes
Exports of goods & services (current price US$)	UNSD, National Accounts Estimates of Main Aggregates
Imports of goods & services (current price US$)	UNSD, National Accounts Estimates of Main Aggregates
GDP (current price US$)	UNSD, National Accounts Estimates of Main Aggregate
Cost of freight in total value of imports (%)	OECD (2011)
Proportion of total freight carried by maritime (%)	Assumption
Imports from EU27 carried by sea (current price Euros)	Eurostat
Export to EU27 carried by sea (current price Euros)	Eurostat
Imports by HS product group (current price US$)	Comtrade
Exports by HS product group (current price US$)	Comtrade

In order to translate the increase in aviation costs into an increase in import prices it is necessary to use an estimate of the proportion of maritime costs in total import value. Here we use values from OECD (2011). It is necessary to make an assumption about the proportion of total freight carried by maritime shipping. For the case study economies we have calculated these based on values of exported and imported goods from COMTRADE data.

Scenarios MBM 3a-d apply only the EU trade with the case study economies. It is therefore necessary to calculate the share of exports to and imports from the EU27 carried by sea as a proportion of total exports and imports carried by sea for each of the case study economies. Figures for the value of trade carried by sea between the CSEs and the EU27 were taken from Eurostat for 2011 and, after conversion to US$, divided by estimates of the total value of exports and imports carried by sea for the CSEs in 2011. This 2011 share is assumed to prevail until 2025.

Data Processing

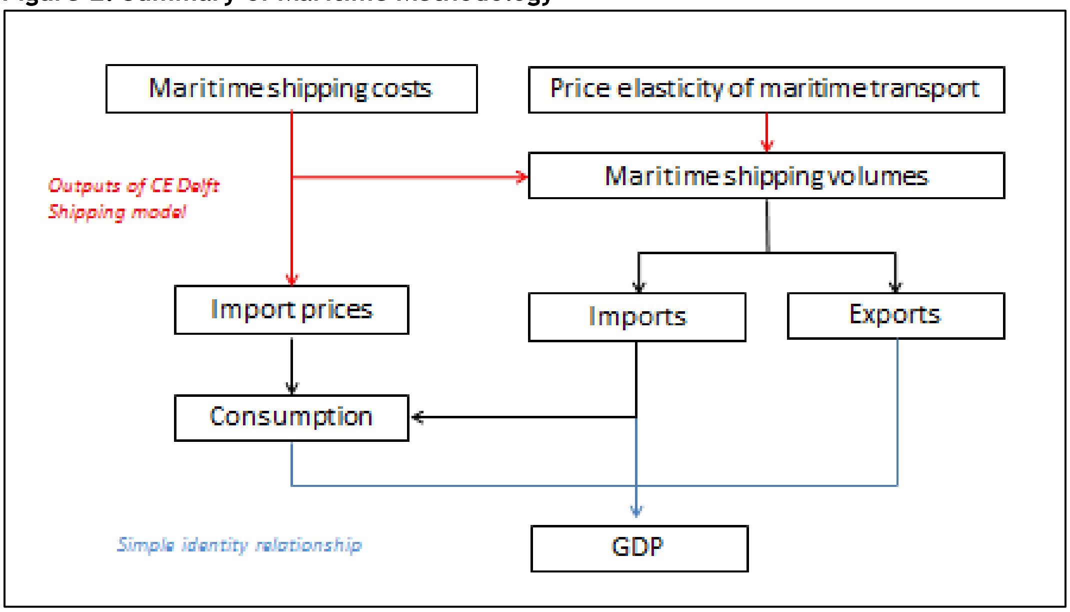
The national accounts data has been projected forward using the same methodology as described in the aviation section above.

Methodology

1) Freight

Figure 1 summarises the methodology used to estimate the percentage impact, attributable to maritime freight of the policy scenarios on GDP. The first stage of the process is to use the CE Delft shipping model outputs to calculate the percentage change in import prices. The percentage increase in maritime transport costs is taken directly as an output from the shipping model. This is then weighted by the share of freight in the total value of imports and the proportion of total freight carried by maritime shipping to yield an estimate of the percentage change in import prices. In the case of scenarios MBM 3a-d, which only apply to trade between the CSEs and the EU, this estimate is additionally weighted by the share of imports from the EU27 carried by seas in total imports carried by sea.

Figure 2: Summary of Maritime Methodology



The percentage change in consumer prices is then calculated as the percentage change in import prices weighted by the share of imports in total domestic consumption. This is calculated using the UNSD estimates of the main national accounts aggregates. Domestic prices are assumed to remain unchanged. This increase in consumer prices represents the percentage reduction in real income and is therefore inversely proportional to the reduction in consumption.
The percentage change in import and export volumes is estimated by applying an estimate of the price elasticity of demand for maritime transport to the percentage increase in maritime transport costs (both taken from the CE Delft shipping model). This is weighted by the proportion of total freight carried by maritime shipping and, in the case of scenarios MBM 3a-d, the share of imports (exports) from (to) the EU27 carried by sea as a proportion of all imports (exports).

A further change in import volumes is calculated as the percentage change in consumption weighted by the share of imports in total domestic consumption. The aggregate percentage impact on GDP is then calculated by accounting identity i.e. as the percentage change in imports, exports and consumption weighted by their shares in GDP.

2) Revenue Recycling

As with aviation ETS auction revenues, the impact of the recycling of maritime ETS revenues is represented by an increase in total domestic consumption. The revenues raised are provided as inputs to the analysis based on country's share in global maritime trade by value. These revenues are then adjusted to reflect the share of free-allowances and/or alternative carbon price in each of the scenarios. The percentage impact on GDP arising from revenue recycling is then calculated as the percentage increase in total domestic consumption as a result of the revenues weighted by the share of total domestic consumption in GDP.

3) Total

The total impact on GDP for each scenario is calculated as the sum of the percentage impact on GDP arising through the effect of the MBM on freight and the percentage impact on GDP arising from the recycling of the revenues.
It should be noted that a positive net impact on GDP is found to arise when

- the share of imports in GDP is large relative to the share of exports in GDP; and/or
- the percentage change in cargo from imports is greater than or close to the percentage change in cargo for exports.

This can result in the negative impact of a reduction in exports being outweighed by the reduction in imports, which by accounting identity has a positive impact on GDP.

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