Economic Incentives to Reduce Shipping Emissions in Panama

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Background

The Panama Canal (the Canal) is an important, high-volume, strategic shipping route between Atlantic and Pacific states. In 2012, over 14,500 vessels transited the Canal (ACP, 2012). Since the US ceded control of the Canal to the Panamanians in 1999, it has been run by the Panama Canal Authority (ACP) as a revenue-generating enterprise. The canal generated revenues of $2.4bn in 2012, equivalent to more than 6% of Panamanian GDP (www.worldbank.org, 2013). The Panama Canal is also in the late phases of an expansion, due to be completed in June 2014. The newly built third set of locks will be able to accommodate larger vessels, with an increase in vessel capacity from 5000 TEU (twenty-foot equivalent units) up to 13,000 TEU. The new locks are projected to lead to a 21.5% increase in vessel transits and a 55.2% increase in tonnage (Pagano et al., 2012). While Panama benefits economically from the Canal, little is known about the impacts of shipping emissions in the region.

Ships are one of the most cost-effective methods of moving large volumes of cargo; however, ships also contribute non-trivial amounts of harmful emissions to the atmosphere and by deposition to terrestrial and aquatic ecosystems. As a by-product of combustion of heavy fuel oil or residual oil, which has a large percentage of sulphur compared to distillate fuels, ships release significant amounts of sulphur oxides (SOx) and particulate matter (PM) into the atmosphere. When these aerosols are inhaled, SOx and PM have significant deleterious effects on human health such as pulmonary and cardiac distress, especially in at-risk populations such as the elderly and very young children. Corbett et al. (2007) estimate that shipping emissions are linked with approximately 60,000 premature deaths worldwide each year; regional studies with finer resolution often estimate higher impacts than the global study by Corbett et al (2007). A 2013 study estimated that, in 2005, 14 million life years were lost due to PM from ships in the European Union (VITO, 2013). The US EPA estimates that if US EEZ emissions went unchecked in the year 2020 then up to 14,100 deaths in the US would be attributable to ships. (EPA, 2009a).

Many Latin American cities have poor air quality resulting from less regulated industrial processes and aging automobile fleets (Zell et al., 2009). While efforts to improve fuel and industry standards are being implemented in some countries, Cifuentes et al. (2005) estimate that over 100 million people are exposed to air quality levels that are significantly above World Health Organisation guidelines of 50μg/m^3 PM10 over 24 hours (WHO, 2006). Contributions of SOx and PM from shipping are not well characterised in Latin American countries and warrant further scrutiny, especially in countries with high levels of shipping activity such as Panama.

Junker et al. (2004) estimated particle back trajectories for PM and black carbon (another polluting particle emitted by combustion engines) measured at an army base on the Caribbean shore of Panama close to the canal in 1976-79. The authors estimate that 9.75μg/m^3 of PM, black carbon, and other aerosols originated from maritime sources, i.e. ships. While these data are older and reflect particle emissions in the late 1970s, it is important to note the estimated particle back trajectories, which show abundant particle tracks originating off the coast of Panama and demonstrate the importance of ship emissions in the area.

Notteboom (2011) notes, "harmful emissions represent a social cost to society particularly when these environmental effects are not properly internalised in the transport price." Recent efforts by coastal states to control ship emissions fall into two main categories: command and control strategies and market-based incentives. Command and control strategies have been successful at the international level. Under the MARPOL VI treaty, the International Maritime Organisation (IMO) has approved four emission control areas (ECA) in which all large vessels must reduce SOx and PM emissions to a defined standard based on fuel sulphur content. ECAs are currently established in the US exclusive economic zone (EEZ), the Baltic Sea, the North Sea and English Channel, and the US Caribbean Sea. In order to comply with ECA standards vessels must either switch from using residual oil (RO, 2.7-4.5% Sulphur by mass) to lower sulphur distillate fuels (1.0% S, 0.5% S, or 0.1% S) or use scrubbers, which absorb up to 99% of SOx and PM from exhaust gasses. The timeline and levels of SOx abatement required in an ECA are shown in figure 1.

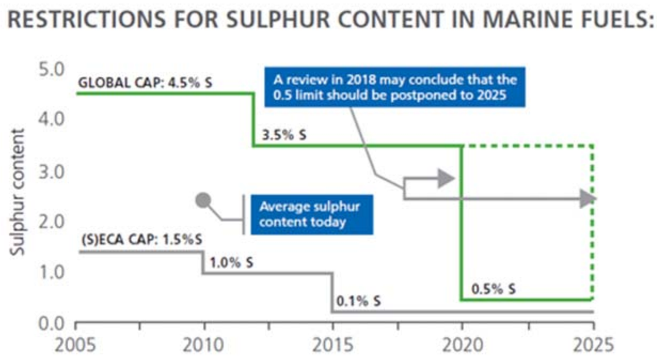

Figure 1. Global and ECA fuel standards

DNV.com, IMO.com

Market-based incentives have also had some success, and such schemes are typically administered at more local or regional levels than IMO ECAs – similar to a scale for unilateral action by Panama. Sweden implemented a sulphur reduction scheme that offered a lower fairway transit fee to vessels that complied with lower sulphur emission standard in Swedish waters. Within five years Sweden observed a 75% reduction in SOx levels and over 80% vessel participation (Kågeson, 1999). Other successful market strategies exist such as emissions trading and the Green Award certification scheme, through which participating ports offer differentiated port dues and preferential treatment for environmentally compliant vessels.

Application of an economic instrument to reduce shipping emissions in Panama has potentially far reaching impacts. Given the Canal's influence over global shipping, it is possible to influence a large amount of change for a relatively small amount of enforcement effort in Panama. If Panama were able to attain ECA-like emission reductions, without going through the sometimes prohibitive IMO process and instead use an economic instrument, then it could set the stage for other countries in a similar position to follow suit.

Purpose

Analysis of the costs and human-health benefits of potential emission reduction strategies for large ocean-going vessels transiting Panamanian waters and the Panama Canal in order to determine the optimal level at which to set a pollution tax or other economic instrument.

Approach and Methods

First, in order to determine an emissions profile for a vessel transiting Panamanian waters and the canal, GIS software was used to create a network of shipping lanes. Shipping lanes were derived from the ICOADS emission inventory and the Oak Ridge National Labs global shipping network. Three possible routes exist within the Pacific EEZ: Asia/West Coast Central America/West Coast North America, Oceania, and West Coast South America. Four routes exist within the Atlantic EEZ; East Coast Central America, US Gulf Coast, US East Coast/Europe/Africa, and East Coast South America. Routes are shown in fig. 2.

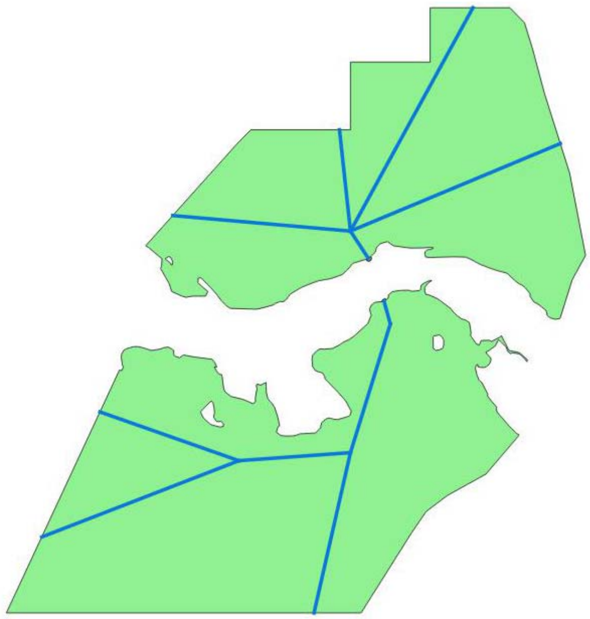

Figure 2. Panamanian EEZ with major shipping lanes drawn

The length of each route segment was used to calculate the time taken for a vessel to transit based on average cruising speeds listed in the US EPA document "Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories" (US EPA, 2009b). Ship emissions follow the mathematical form

Emissions = Installed Vessel Power x Load Factor x Activity x Emission Factor

Installed vessel power refers to the total power of the vessels main engines, measured in kilowatts (kW). The load factor is the percent of a vessel's total power required to travel at a given speed. Activity, measured in hours (h), refers to the length of time that the vessel is operating in a given mode of transit. The emission factor is related to the size of the engine and denotes the amount of emissions per unit of energy from the engine (g/kWh).

Vessel size and installed engine capacity were determined using 2005 Lloyd's List data, detailing the deadweight tonnage and installed capacity of all large ocean-going vessels on the planet. After selecting only container ships and removing all vessels too large to currently fit in the Canal's locks, installed power was regressed against deadweight tonnage in order to determine the relationship, which is linear. For the purposes of this study I will also use bulk carriers and tankers, which together with container ships comprised over 70% of the transits and tonnage through the Canal in 2012. Vessel transit and cargo data are freely available from the Panama Canal website at www.pancanal.com.

Initially emissions were calculated for slow speed diesel container ships. Slow speed diesel engines were used as these burn RO, and are installed in the majority of large ocean-going vessels. Emission profiles were calculated for four fuel types, 2.7% S, 1.0% S, and 0.5% S and 0.1% S, which correspond with available marine bunker fuels due to IMO ECA regulations. Current estimates use spot prices for marine fuels in order to estimate the cost of fuel switching. Scrubbing costs were estimated using closed-loop retrofit scrubbers as described in Campling et al. (VITO, 2013). As mentioned previously, further analysis of fuel prices is required, using long-range forecasts in order to determine the sensitivity of emissions as related to fuel price. Sensitivity analysis of load factors is also required, as load factors can vary considerably by ship type and speed and have a direct influence on emissions.

When determining damages, Cifuentes et al. (2005) coincidentally investigated the economic benefits of particulate emission reductions, which provides an important platform for this work. This study will also need to incorporate the impacts of acidifying gases such as SOx on top of PM10 emissions in order to more completely understand the total economic benefit of reducing emissions. Further literature search is required in order to determine best practices for estimating damages from emissions to human health and possibly aquatic and terrestrial ecosystems.

Once costs and damages are accurately characterised, it will be useful to compare setting the emissions tax at different levels: tax equal to marginal abatement cost, tax equal to marginal damages, and a pigovian tax on emissions. It will be important to consider alternatives available to shipping firms such as route switching in relation to the level of the tax in order to avoid incentivising perverse behaviours. It will also be important to consider long-range Canal transit forecasts and creative market solutions such as fleet averaging, emissions trading, and scrubber capital cost financing.

Initial Progress and Sample Intermediate Results

There are several ways to consider setting a market signal: setting fees or taxes at levels that are pigovian, or equal to the marginal cost of the most expensive control, or equal to the marginal cost of the least expensive control. Each of these has implications for policy makers and indirect effects on technology innovation and operational behavior choices. Kågeson (1999) recommends that tax rates be based on the marginal cost of reducing emissions in the absence of good information on the marginal damages from emissions.

Following the marginal cost of control idea, preliminary data suggest that the additional cost for a slow speed diesel container vessel to fuel switch from RO to 1.0% sulphur fuel would be $1600/ton pollutant abated or $6.60/TEU for a 10,500 deadweight ton vessel. Abatement costs per TEU or per ton cargo are inversely proportional to vessel size. Panamanian tolls for container ships are assessed on a per TEU basis, it follows that vessels would comply with 1.0% sulphur standards if the emissions tax were set greater than $6.60, as it would be cheaper to fuel switch and comply. The problem with this example is that as volatile fuel prices vary or trend (increase or decrease), the marginal cost of compliance will covary. Similarly, estimates show that container vessels could scrub to the 0.1% sulphur standard for an additional cost of $17.60/TEU meaning that if the tax were set just higher than an additional $17.60/TEU for non-compliance then vessels could adhere to the strictest IMO 0.1% sulphur emissions regulations by scrubbing at lower cost than the tax. Further analysis of abatement costs is required, including considering projected fuel price volatility, refining scrubbing cost analysis, considering vessel types other than container ships, and analysis of route switching costs.

Pollutant	$/ton pollution avoided		$/tonne cargo		$/TEU	
	1.0% S	0.1% S	1.0% S	0.1% S	1.0% S	0.1% S
SOx	$1600	$2860*	$0.45	$1.20*	$6.60	$17.60*
PM (2.5 or 10)	$90	$190*				

Table 1. Least abatement costs to the 1% and 0.1% Sulphur levels for a 10,500 deadweight ton vessel (*denotes scrubber abatement cost)

It is also important to note that it may not be the most economically efficient practice to set the tax at the marginal abatement cost, and instead should consider setting the tax equal to marginal damages. Cifuentes et al. (2005) conducted a meta-analysis study of Latin American cities to determine the "real economic value of improvements in air quality." As mentioned previously, Cifuentes et al. (2005) estimate that over 100million people in Latin American cities are subject to air quality that does not meet WHO international guidelines. The authors state that PM10 (particulate matter < 10μm) concentrations in Panama City for the period 1997-2003 were 77.1μg/m^3, which is 54% greater than the 50μg/m^3 WHO global guidelines. PM10 concentrations from ships are proportional to sulphur emissions and efforts to lower sulphur emissions also reduce PM10 exhaust levels. Coincidentally, Cifuentes et al. estimate the economic benefit of reducing PM10 levels by 10%, and to the 50μg/m^3 WHO guideline, levels that roughly align with expected shipping reductions as previously described by Junker et al. and ICOADS/EDGAR emissions estimates, which attribute 16-40% of Panamanian PM10 and 20-50% of SOx to ships. Long-range estimates for statistical lives saved each year by emission reductions are 41 lives saved for a 10% reduction, and 160 lives saved for a reduction to WHO guideline levels. Cifuentes et al. go on to estimate the total benefits in Panama City based on willingness to pay and value of statistical life measures at $130million for a 10% reduction and $480million for a reduction to 50μg/m^3. It is important to note that these results only consider health impacts from PM10 in Panama City and do not include SOx and PM10 reduction benefits or environmental damages for the country of Panama as a whole. In comparison, Wang and Corbett (2007) estimate the benefits of reducing SO_2 emissions along to US West Coast to be between $98million and $284million based on US values for loss of economic productivity, value of a statistical life, and environmental damages. These initial estimates of the benefits of PM10 reduction warrant further analysis and lend themselves well to comparing the emission abatement costs to the damages from ships in order to determine what an economically optimal emissions reduction instrument might look like in Panama.

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Data

ACP (2012) Panama Canal Transit Statistics www.pancanal.com

Emissions Database for Global Atmospheric Research (EDGAR) available online at http://edgar.jrc.ec.europa.eu/index.php#

ICOADS, AMVER, AMVER-ICOADS available online at http://coast.cms.udel.edu/GlobalShipEmissions (Currently unavailable)

Lloyd's List Maritime Intelligence, 2004

Target Journals

Journal of Environmental Economics and Management
Scope and Author guide:
http://www.elsevier.com/journals/journal-of-environmental-economics-and-management/0095-0696/guide-for-authors

Maritime Policy & Management
Scope and Author guide:
http://www.tandfonline.com/action/authorSubmission?journalCode=tmpm20&page=instructions#.UkSzYRZ4ftI

Tasks

1. Initial literature review (complete as of September 2013)

2. Propose AP analysis (submitted 30th September, 2013)

3. Estimate shipping emissions and geospatial activity around Panama (complete)
    a. Preliminary results for containerships
    b. May update using better "best" practices for load factors and shipping forecasts

4. Estimate cost of no action for shipping fleet
    a. Include containerships and expand to include tankers and bulk carriers (75% of canal transits)
        i. Possibly expand to include specialty types such as cruise vessels

5. Estimate cost of compliance - Marginal Abatement Cost (Kågeson approach)
    a. 1% S (fuel switch) - methodology complete, possibly update as above (3b)

    i. Sensitivity analysis for fuel price
    ii. Outputs: $/ton S avoided, $/year operation, % change $ operation, $/tonne cargo, $/TEU (containership only)
  b. 0.1% S fuel (both scrubbing and fuel switch) - methodology complete
    i. As above

6. Estimate potential benefits
   a. Literature review building on Cifuentes et al. air quality
      i. Possible: atmospheric modeling of ship particle movement
   b. Estimate the Pigovian tax for Panama

7. Compare cost of compliance with potential benefits.
   a. MAC vs. Pigovian
      Consider:
      i. Ship operator perspective
      ii. ACP perspective
      iii. Panama Health Agency perspective

8. Consider these results in terms of possible policy action
   a. Compare IMO MARPOL ECA with local economic incentives
   b. Consider command and control mechanisms at Panama level
   c. Consider mechanisms for imposing MAC/Pigovian fee
   d. Analyse applicability in other regions

Due Dates

Paper outline: January 2014
First draft: March 2014
Final Draft: April 2014
Defense: May 2014

Committee Composition

Major advisor: Professor James Corbett, School of Marine Science and Policy
Reader #1: Professor George Parsons, School of Marine Science and Policy
Reader #2: Professor Sunny Jardine, School of Marine Science and Policy