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Modelling emission control taxes in port areas and port privatization levels in port competition and co-operation sub-games

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ABSTRACT

Using a game theory approach, this paper analyses a situation in which the government imposes a certain emission tax on vessels and port operations for emission control in port areas. Two ports are considered: a purely private port and a landlord (partial public) port. These two ports are in Cournot or Bertrand competition or cooperation with differentiated service. Our model outcomes lead to the following conclusions. First, the optimal private level of port 2 under Cournot and Bertrand competitions varies between fully private and highly public concerned port, while government will prefer a highly public concerned or close to highly public concerned port in the cooperation scenario. Second, government will have to make more and stricter efforts to enhance environmental protection in the situation of port cooperation (monopoly) than in the case of inter-port competition, and all the optimal emission tax should be always lower than the marginal emission damage. Third, port privatization has a non-monotonous effect on ports' environmental damage in the inter-port competition scenarios and a monotonous decreasing effect in the cooperation scenario. Fourth, the total emission tax revenue is always higher than the overall environmental damage in the cooperative scenario, and it may or may not be able to cover the whole environment damage in Cournot and Bertrand competitions. Finally, the government may face a trade-off among environmental protection, maximizing social welfare, satisfying individual motivation, when considering port cooperation (monopoly).

1. Introduction

Maritime transport is the most environmental-friendly transport mode in terms of emission/fuel consumption per ton of cargo. However, due to its overwhelming share in international cargo shipments, it represents a significant share in global emissions, including GHGs, NO_x, and SO_2. According to the third IMO GHG study of 2014, international shipping emitted 796 million tons of CO_2 in 2012, about 2.2% of total global CO_2 emissions for that year, compared to 885 million tons in 2007, about 2.8% for that year. Ships emitted respectively 15% and 4–9% of the global NO_x and SO_2 (Tzannatos, 2010).

Compared to the overall emissions of the shipping industry, emissions in port areas are relatively small. Given the proximity of most ports to urbanized areas, the emissions in ports greatly impact on port and contiguous community areas (Saxe and Larsen, 2004;

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Dore et al., 2007). A study found that in a certain port, ship emissions in ports are estimated to be about ten times higher than the emissions from port operations (Habibi and Rehmatulla, 2009). The GHGs in Barcelona port area were found to be equal to the GHGs emitted by land activities (Villalba and Gemechu, 2011). Emissions of NO_x and SO_2 in port areas are highly linked to regional air quality given the impact of NO_x and SO_2 on acidification and NO_x on eutrophication and tropospheric ozone formation. They also affect public health and ecosystems (lung cancer, allergies, and asthma), particularly in coastal communities (Corbett and Fischbeck, 1997; WHO, 2000; Eyring et al., 2010; Song, 2014).

In recent times, a number of ports run by a local or central authority have begun or are planning to implement programs or policies which address these pollution problems (Gibbs et al., 2014) either on ships or in ports. To reduce ship emissions, local authorities can set minimum technical standards for ships. This measure can include compulsory fuel switch programs (e.g. the use of low sulfur fuel and MDO) or the installation of emission control equipment on ships (e.g. scrubbers). The port authorities of Rotterdam, Antwerp, Amsterdam, Le Havre, Hamburg and Bremen in cooperation with International Association of Ports and Harbors (IAPH) have developed the Environmental Ship Index (ESI) to give scores to ships ranging from 0 to 100 with 100 points corresponding to a zero-emission ship. Vessels with a score above a certain threshold can be granted a discount on port dues in the participating ports of call (Lam and Notteboom, 2014). Such voluntary schemes are aimed at giving ship owners and ship operators a price incentive to invest in greener ship technology. While port users are rewarded for being greener, it is more important to assess whether the price incentive can cover the extra cost of being greener. To reduce the emissions related to port operations, many ports have the pressure of replacing fossil fuel-driven facilities/vehicles by electricity-powered or hybrid ones. For instance, the port of Long Beach implemented a green port policy to facilitate a shift to renewable power sources and self-generation systems, thereby reducing diesel particulate emissions, nitrogen oxides, sulfur oxides, and greenhouse gases by 85%, 50%, 97%, and 21% respectively at the cost of approximately USD 500 million from 2005 to 2014.

These programs above result in a de facto rise in the cost of port calls due to various emission reduction investments. Given that pollution can be measured and traced (Villalba and Gemechu, 2011; Geerlings and Van Duin, 2011; Gibbs et al., 2014), many studies started to focus on emission taxes. Wang et al. (2009) firstly proposed the idea of charging emission taxes with pollution abatement measures. Tseng and Pilcher (2016) proposed a ship emission tax in port/berth, and considered it valuable and viable at a policy level. Zheng et al. (2017) investigated a possible port emission regulation impacted by incomplete information. Sheng et al. (2017) investigated the economic and environmental effects of a unilateral maritime emission regulation vs. a uniform maritime emission regulation. So, governments are able to directly design and implement environmental regulations by imposing emission control taxes on the polluters in the port area and to use the proceeds to clean up the pollution effects (adapted from Wang et al., 2009).

These measures/programs and the possible emission control taxes are expected to have an effect on port competitiveness and on inter-port competition. For example, Notteboom (2006) found that switching from HFO to MGO will increase ship cost significantly due to the high bunker cost, so that, eventually, it will affect port competitiveness. Notteboom (2011) also concluded that the compulsory use of low sulfur fuel for roro shipping in the Baltic and North Sea leads to increases in freight rates and a potential traffic loss/shift to road haulage (the so-called modal back shift). Wang et al. (2014) mentioned the influence of setting an Emission Control Area (ECA) in the Pearl River Delta and found that “fuel cost rise (due to setting ECA) may give a disadvantage to ports within the Pearl river Delta by suffering traffic loss…”. Tseng and Pilcher (2016) referred to the concerns of port operators and government on the negative impact of possible emission taxes on port traffic, especially considering the fierce inter-port competition in the region.

The authorities above, including port authorities and municipal or central governments, are often the key (co-)initiators of the development of measures to lower emissions in ports, and are heavily influenced by the port governance and ownership structure. Since the 1980s, port privatization is becoming increasingly common worldwide. Although the situation differs from port to port, according to the general category (ownership structure) defined by The World Bank (2007), service/tool (public) ports and landlord ports are generally considered to have a strong focus on public objectives (i.e. maximizing consumer surplus), while fully private ports will mainly focus on profits only (see Table 1). Generally, the higher the public/state-owned investment, the stronger the focus on the overall social welfare of the port, since the investments from public sources have to satisfy more diversified/combined objectives, e.g. even including indirect employment linked to the port. For instance, certain special public ports can be found in China. The container terminals in Shanghai are mainly owned and operated by Shanghai International Port Group (SIPG), whose top four shareholders are Shanghai Supervision Committee of State-owned Assets (31.36%), Adroit Investments Limited (24.04%, a HK-based private company, a subsidy of China Merchants Port Holdings Company Limited, state level), Shanghai Tongsheng investments Ltd (19.86%, a subsidiary of Shanghai Supervision Committee of State-owned Assets, municipal level) and Shanghai Chengtou Ltd (4.21%, a subsidiary of Shanghai Supervision Committee of State-owned Assets, municipal level). Its top objective (vision), as found on its official website, is to serve as the gateway port in the Yangtze River Delta and to keep its position as the world’s biggest container port in throughput terms offering a diversified service. Meanwhile, the objectives of the state/municipal owned investment companies as its shareholders, are also to achieve a high ROI. In other words, its primary objective is to guarantee a certain threshold throughput (consumer surplus) and to generate enough spillover effects, followed by a second objective of achieving a high profitability. Similarly, also landlord ports typically combine public and private objectives. For instance, the port of Antwerp in Belgium is a typical landlord port. The port authority owns and manages the sites in the port area, and makes them available to port companies for their activities on the basis of concession agreements. Its concession policy is aimed at keeping a balance between promoting sustainable development (i.e. the balance between public objectives and private objectives, e.g. throughput guarantee, gateway port function, attracting investment, profits, etc.) and making the most efficient use of the available land (i.e. related to the agreements with port operators about the profit allocation through concession). These two examples show that public ports and landlord ports both pursue differentiated public and private goals to satisfy their stakeholders. Compared to the public port/landlord port, a private port (i.e. owned and operated by a private port authority and/or private port operator) also shares certain public objectives, but its