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Modeling collusion-proof port emission regulation of cargo-handling activities under incomplete information

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ABSTRACT

This study models the emission regulation of a port's cargo-handling activities when the regulatory government agency lacks complete information on the cost of reducing emissions for the port. The goal is to identify rules for determining the optimal port charge and capacity to allow port emissions to be regulated in an environment with incomplete information. We evaluate the effect of introducing a risk-averse environmental monitor as a supervisor to provide the government with additional information (a signal) on the port operator's emission reduction cost. To prevent the environmental monitor from colluding with the port operator, we develop a collusion-proof regulation scheme based on the principal–agent theory. The scheme is modeled as a bi-level problem faced by the government and the monitor. We find that, compared to the case with complete information, collusion-proof regulation do not distort optimal port charges only when the port operator is efficient and has low emission reduction costs. When distortion does occur, it depends on the monitor's degree of risk aversion and the accuracy of the signal about emission reduction cost. Besides, information asymmetry leads to less cargo throughput, a lower emission level, and reduced port capacity. Such regulation-induced downward distortion can be either alleviated or aggravated by the collusion-proof regulation, depending on the quality of the information received by the environmental monitor. Our theoretical models are tested using a case study based on container terminals in the Port of Shanghai. The numerical results suggest that a risk-averse environmental monitor can improve port user's social welfare in the presence of imperfect information.

1. Introduction

As a major interface between land and water transportation, ports play an important role in international supply chains. Most of the world's ports have experienced rapid throughput growth in recent years. For example, the total throughput of Chinese ports reached 11.2 billion tons in 2014, a 4.8% rise over the previous year. At the same time, however, greenhouse gas emissions and other air pollutants from ports have also been growing. According to Entec (2005), about 1% of total shipping-related emissions are produced at seaports. As such emissions pose health risks and other external costs

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(e.g., contribution to global warming), there is increasing pressure on governments worldwide to tighten the regulation of port emissions.

The main sources of port emissions are ocean vessels, harbor craft, cargo-handling equipment, and rail and road vehicles associated with port operations (Chen et al., 2013). The Starcrest Consulting Group (2011) reports that 20% of the emissions at the Port of Los Angeles are generated from cargo-handling activities, encompassing emissions from harbor craft and cargo-handling equipment. The regulation of emissions from ports' cargo activities has thus become a key topic in port emission control.[1] Although studies have examined a variety of issues related to port emission control (see Section 2 for a comprehensive review), few have considered the difficulties faced by governments in developing feasible and effective regulations, most notably the lack of sufficient information on port operators' emission reduction costs. Although there have been proposals to use incentive regulation tools to elicit private information from port operators (POs), these tools may themselves affect port behavior, and hence distort the regulation results. Therefore, the design of effective regulation schemes in the face of incomplete information constitutes a crucial problem in developing effective port emission control policies.

In Shanghai, China, the city government is planning to reduce the average density of PM 2.5 from 60 $\mu g/m^3$ to 25 $\mu g/m^3$. In order to achieve this ambitious target, the city government tries to prompt stricter emission standards in the production processes of all industries including the port sector. Policies include subsidy for industrial restructuring and setting up special funds to support the saving and cleaner production of energy. In the port industry, the discussions are focused on using equipment powered by cleaner energies, such as replacing diesel-powered rubber-tired gantry cranes (D-RTGs) with electricity-powered RTGs (E-TRGs). The main policy being planned is to subsidize the POs who switch to cleaner production. However, several important questions remain to be answered before effective policies can be designed and introduced, such as (1) How to identify the right PO to subsidize? Which PO is "emission-reduction-efficient" ? (2) How to design a subsidy policy that incentivizes the PO to reduce emission and meet production requirements at the same time? and (3) If the government does not have sufficient information to identify the PO's emission reduction costs, could an information "assistant" be hired to help the policy implementation? If so, what can be done to prevent possible collusion between the assistant and the PO? Similar problems may arise for the design and implementation of other emission policies, because in most cases a regulator has less information than the firms being regulated.

In this paper, we propose a set of models for use in the development of a scheme to regulate port emissions arising from cargo-handling activities based on the assumption that information on the PO's cost to reduce emissions is not fully available to the government (i.e., the regulator). Our models generate regulatory decisions to control port cargo volume and emission levels under incomplete information. To improve the regulator's access to information, a risk-averse environmental monitor (EM) is introduced as an information supervisor. The EM has more professional knowledge than the regulator, and is able to obtain additional information, or a "signal," on the PO's emission reduction cost. However, it is possible that the EM will collude with the PO,[2] thereby leading to inefficient outcomes and reducing port user's welfare. To address the potential for collusion, we propose a collusion-proof regulation framework, and compare the results of regulation in the complete and incomplete information settings. The models are subsequently tested and validated using a case study based on the Port of Shanghai.

Our work contributes to port emission regulation in the following ways.

(i) The proposed model emphasizes the information asymmetry that exists in emission regulation. Previous studies have investigated the port regulation problem considering imperfect information on POs' efforts to increase operational efficiency (Sauri and Robuste, 2012; Wang and Pallis, 2014) and reduce operating costs (Zheng and Negenborn, 2014). However, to the best of our knowledge, few have considered emission control in an environment characterized by incomplete information on POs' emission reduction costs. The lack of information on such costs not only affects the results of emission control, but also port charges and capacity, and thus port cargo throughput. Here, we consider regulation schemes that can prompt a PO to reveal private information on its emission reduction costs in a truthful manner. We investigate how the government uses regulated port charges and capacity rules to control a PO's emission levels.

(ii) To help regulators to improve their information access, we introduce an EM who operates as an information supervisor in a three-tier regulation system, and then model a collusion-proof regulation scheme as a bi-level problem faced by the government and the EM. Collusion-proof regulated port charges and capacity rules are obtained in the incomplete information setting with the aim of improving emission control. The proposed collusion-proof regulation scheme leads to the following novel findings.

(1) The presence of incomplete information poses no distortion in the collusion-proof regulation, if the operator is efficient, i.e., he has low emission reduction cost. However, for an inefficient operator (with high emission reduction

[1] The remaining 80% of port emissions are generated by port users, such as vessels, trucks, and trains, whose activities cannot be easily controlled by port operators. Because numerous studies discuss this issue (see the detailed review in Section 2), we focus here on port emissions produced directly by port operators' activities.

[2] The government hires the EM to obtain more precise information on the PO's emission reduction cost by leveraging the EM's professional knowledge and experience. However, the PO may find ways to influence the EM's report to the government in its own favor (resulting in EM–PO collusion). Laffont and Tirole (1993) list several possible ways to do so, including bribery and future job opportunities to the employees.