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Measuring foregone output under industry emission reduction target in the transportation sector

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ABSTRACT

Numerous countries have implemented or are considering a range of policies to lower emissions from transportation. An analysis of the impacts of environmental regulation is a crucial issue, which has not been properly highlighted in the transportation literature, particularly in terms of the foregone output by such regulation. This study develops a novel DEA model that measures the foregone output when the industry emissions target is imposed. This model reflects the real regulatory process more appropriately than other models in that the authority in charge sets the emission reduction target first, and the transport operators respond to it. In addition, the model can test the industrywide impacts over a wide range of emission target values, which can help policy makers determine the optimal emission target. Finally, the proposed model was applied to the port industry in Korea. The results suggest that Korean ports can reduce their emissions by a maximum of 239,850 tons of CO_2, which accounts for 13% of the total emissions in 2010. The 13% reduction in emission, however, would result in $ 91,109,000 of foregone cargo traffic to the Korean economy. In addition, the foregone cargo traffic increases at much faster rate than the emission reduction rate. For example, the shadow price of emission differs by 2.25 times between the most moderate and strictest emission targets. This suggests that the government needs to impose moderate emission targets at the initial stages if it decides to minimize the regulatory impacts on the industry.

1. Introduction

Transportation has a range of external effects on mankind, such as atmospheric pollution, noise pollution, and accidents. Atmospheric pollution arising from the transportation sector has been a major concern in the past several decades, due to ever deteriorating air quality, but there is an ever increasing demand for the sector in many parts of the world. The pollutants emitted by transportation can affect the environmental conditions of local, regional, and global areas differently by the type of the pollutants. Local effects inflicted on the population in the immediate vicinity of the source are caused by nitrogen oxides (NO_x), hydrocarbons, ozone, particulate matter (PM), carbon monoxide, and sulfur dioxide (SO_2). Regional effects are caused mostly by SO_2 and NO_x, leading to acid rain and photochemical smog. The global effects are represented by 'global warming', which is one of the most challenging issues to both current and future generations (Cullinane and Edwards, 2010). The United Nations Intergovernmental Panel on Climate Change (IPCC) listed 27 greenhouse gases (GHG) as major causes of

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the global warming (UN IPCC, 1996) and the Kyoto Protocol grouped these into six categories (UN, 1998), of which carbon dioxide (CO_2) accounts for approximately 85% of GHG.

The transportation sector is a major contributor of GHG emissions. According to the International Energy Agency (IEA), the industry accounted for 23% of world GHG emissions in 2013 and showed significant growth in the volumes for the last two decades: the road sector emitted 68% more GHGs than the 1990 level, and marine and aviation bunkers emitted 64% and 90% more, respectively, than that of 1990 (IEA, 2015a). To address the emissions in transportation and other sectors, numerous international climate regulations have been set in motion. The first coercive agreement to reduce GHG was the Kyoto Protocol. The first phase of the agreement (2008–2012) required the participants to reduce their domestic emissions by approximately 5% compared to the 1990 emission level. The second phase (2013–2020) has been ineffective thus far because it requires ratification by at least 144 countries, which has not been met by the majority of countries. The Kyoto Protocol has limitations in that the emissions in the United States and developing countries remain unregulated, restricting the coverage of the agreement to less than 14% of global GHG emissions. Recently, a more extensive GHG agreement than the Kyoto Protocol, called the Copenhagen Accord, was reached at the 21st UN Conference of the Parties in December 2015. This agreement is to be enforced in 2020–2025 with the ambitious objective of controlling the global temperature rise to 2 °C above pre-industrial levels. Unlike the Kyoto Protocol, the Copenhagen Accord is joined by both developed and developing countries, whose coverage is >80% of global emissions (IEA, 2015b).

In parallel with these movements of environmental regulations, several countries have implemented or are considering diverse policies to lower the emissions by transportation mode. To tackle road sector emissions, the European Union (EU) have set stricter emission reduction targets for new passenger cars. Car manufactures need to improve the engine quality from the 2007 vehicle average of 158.7 g of CO_2 per kilometer (g CO_2/km) to 130 g CO_2/km by 2015. The target will become stricter at 95 g CO_2/km by 2021, which will induce a 40% emission reduction compared to the level in 2007. Similarly, heavy goods vehicles have been a major subject of progressively tightening environmental standards, which are known as the EURO emission standard since the early 1990s. NO_x and PM were the major targets of the standards, through which the vehicles entering in the EU market after 2013 emit an almost negligible level of these two pollutants (Cullinane and Edwards, 2010). In the shipping sector, the International Maritime Organization (IMO) has adopted several environmental regulations to reduce GHG, SO_2, and NO_x over time (see Cullinane and Bergqvist, 2014; Miola et al., 2011 for the details). In addition, some ports in the U.S., such as the Port of Los Angeles/Long Beach, the Port of New York/New Jersey, and the Port of San Diego, designated a reduced speed zone (RSZ) with a view to reducing the emissions from ships. Moreover, other policy options for lowering the ship emissions, such as developing slender design, upgrading propeller, and installing hydrogen fuel cells, have been studied for their potential impacts (Lindstad et al., 2015a). The major GHG regulation in the aviation sector is EU emission trading scheme (ETS) (Preston et al., 2012). In close cooperation with the International Civil Aviation Organization, the European aviation sector has been included in the EU ETS since 2012, and the regulation binds both EU and non-EU airlines operating within EU territory.

In this context, an analysis of the impacts of environmental regulations has been a crucial issue, which has not been properly highlighted in the transportation literature, particularly in terms of foregone output caused by the regulation. The regulation increases the operating costs of transport operators because they need to invest more money to comply with the regulations. They need to install higher standard equipment or pay a higher price for using the same infrastructure used in pre-regulation periods. Consequently, it is plausible that transport operators may undergo a substantial reduction in their production level as the regulation becomes stricter and the compliance cost increases. Moreover, reduction in transportation outputs can be intensified due to asymmetric regulation. That is, transportation operators affected by stricter regulation would be less preferred to their competitors under lenient regulation (Homsombat et al., 2013).

Therefore, an important question arises as to how much will the transportation operators suffer when stricter environmental regulations are imposed. Capturing the industrywide output loss is important for accurately measuring the valid emission abatement costs from a societal perspective because the reduced transport service would decrease the surpluses of both the transport operator and user. Otherwise, governments would set sub-optimal emission reduction targets that fail to maximize social welfare. To the best of the authors' knowledge, no studies in the transportation sector have examined the emission abatement costs from the viewpoint of an output loss. Existing studies and reports investigated other environmental issues in transportation, such as the effects of carbon tax (Brueckner and Zhang, 2010; Lee et al., 2013), outcomes of emission trading (EC, 2013; Wang et al., 2015) and changes in transportation-related emissions when countries promote free trades (Lee et al., in press). These studies, however, did not focus on traffic reduction under different emission reduction target scenarios. Therefore, this paper develops a model to estimate the potential output loss in the transportation sector when an environmental regulation is imposed.

This industrial output loss from the environmental regulation, which is referred to as "foregone output" in literature, has been measured in other sectors, e.g., Färe et al. (1989), Färe et al. (2007) and Picazo-Tadeo et al. (2005). In particular, they developed a model in a data envelopment analysis (DEA) framework, which is a nonparametric method to evaluate the productivity of firms. In their model, the maximum producible output of firms are defined as the initial step, and they calculate the maximum outputs under the "regulated" and "unregulated" regimes. The foregone output is represented by the difference between the maximum outputs under the two. Their model, however, has some limitations for the following reasons. First, they measured the foregone output on an individual firm level initially, and added the individual foregone outputs to obtain an industrywide output loss. This approach is opposite to the real regulatory process, where an industrywide emission target is determined mostly by government. The emission quotas are then assigned to each firm according to the given