Institute of Transport Economics
Norwegian Centre for Transport Research

Summary:

Production analysis in port economics: A critical review of modeling strategies and data management

TØI Report 1390/2015
Authors: Kenneth Løvold Rødseth and Paal Brevik Wangsness
Oslo 2015, 63 pages English language

The main purpose of the report is to provide an overview of the previous research on port economics using production analysis. We comment on the strengths and shortcomings of this literature, and propose novel strategies for modelling port operations. On the basis of our review and discussions, we identify relevant data and modelling approaches for the EXPORT projects' empirical analyses.

This report responds to task 1.1 of Work Package 1 of the research project entitled "Examining the Social Costs of Port Operations" (EXPORT). The report is tailor-made for the researchers contributing to the EXPORT project, but will also be of interest to other researchers in the field of port economics and production analysis.

We find that most of the previous studies on port productivity and efficiency emphasize container terminals using either Data Envelopment Analysis (DEA) of Stochastic Frontier Analysis (SFA) to evaluate technical and scale efficiencies. The majority of studies treat stock input data, such as the number of cranes and tugs. We consider *flow variables* (e.g. the *use* of cranes) to be more relevant for Norwegian ports, especially when considering returns to scale. The reason is that previous studies have found that Norwegian ports exhibit low degrees of capacity utilization.

Externalities which are jointly produced with the cargo throughput is usually not considered by the port economics literature. There are to our knowledge only four relevant production analyses that consider bad outputs from port operations. The EXPORT project can consequentially be expected to contribute significantly to improving and extending this research area.

On the basis of our review on the port economics literature, and its applied data and methods, we identify the following issues that should be addressed by future research:

- Ports are multi-output producers and there may be economies of scope related to the handling of multiple cargo types. The majority of existing studies consider only one cargo type, namely containers.
- Cargo-handling inputs may be cargo-specific or common to all cargo types. This technology structure suggests that a multi-plant or network production model is appropriate for modelling port operations. The drawback of this approach is its extensive data requirement.
- Even for a given cargo-segment, it can make sense to separate port operations into different sub-units. Bichou (2011) argues that a container terminal is comprised of three sub-units; the quay, the yard, and the gate.
- The ports' objectives are guidelines for choosing appropriate function representations and thus efficiency measurements for ports. It is for example not

useful to consider profit efficiency if profit maximization is not considered a desirable objective by the port.

- Most externalities from port operations depend on the ports' activities. Examples include air pollution emissions and noise. Using stock input data to model the generation of externalities (e.g., by a production function approach) may thus provide biased estimates, because it is the use of the equipment, not the amount of equipment, that determines the emissions. It is also a problem that the port economics literature generally applies production analysis techniques intended for real-valued inputs to integer-valued inputs such as the number of cranes and tugs.
- Most studies define returns to scale of port operations in terms of port expansions (e.g., expansion of the port area and equipment stock). In Norway it may be more important to consider expansions of capacity utilization rather than physical expansions of the port infrastructure because of the ports' apparent overcapacities. That is, it may be more sensible to evaluate returns to density (Caves et al., 1984) rather than returns to scale for Norwegian ports.
- Externalities such as noise and air pollution emissions are among the most important externalities caused by port operations, and they have properties that make them suitable for modelling by traditional production analysis. However, emissions to sea and soil are important too, but they are of a more stochastic nature. Hence, traditional production modelling may not be suitable for characterizing these types of joint production. Instead, alternative models developed by the agricultural economics literature on production risk may be appropriate.

Taking into account the state-of-the art in production modelling as well as the available data for Norwegian ports, we close the report by discussing the empirical and methodological aims of the EXPORT project within the field of traditional and environmental port economics. Focusing on environmental port economics, we propose four modelling approaches that can be considered in the proceeding phases of the project:

- Modelling turbidity as a function of the number of ships leaving and entering the port
- Air pollution emissions from ships as a function of the time spent at berth
- Noise and air pollution emissions from land-based port operations
- A risk assessment for emissions to sea and soil