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Explanatory variables driving the technical efficiency of European seaports: An order-α approach dealing with imperfect knowledge

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ABSTRACT

Maritime transport is hugely important for the modern global economy. The increasing development of economic globalization has led to a considerable increase in intercontinental exchanges, stimulating the use of ports and shipping companies with a cheap and quick way to reach most of Europe, Asia, Africa or North America. This study aims to assess the relevance of thirteen exogenous variables, including GDP *per capita,* water depth, management model, and European directional division, on the performance of the seaports using the nonparametric robust output-oriented order-α model. The study also integrates the Stochastic multicriteria acceptability analysis with the order-α model to handle with cases of imperfect knowledge. This problem is not unusual in nonparametric benchmarking exercises and can have very serious effects on performance outcomes. Our findings suggest that none of the thirteen explanatory variables (either external or performance indicator) has a meaningful association with seaports' technical efficiency. This means that the efficiency of resources usage to deliver port services does not depend on features like localization, management model, local richness, and some performance indicators.

1. Introduction

Maritime transport has a great importance to the modern global economy. The European Union is the world's largest trading block, and 80% of its countries use shipping either to import or to export (Oliveira, 2015). There is a great concern for having appropriate networks to ensure the carried load's flow or drainage.

Carriers and seaports are two main components of the international supply chain. Their functions and operating characteristics strictly dependent on the requirements for transported goods. Indeed, the physical nature of these products leads to different ship designs as well as different handling ways. Port services are provided by several stakeholders (Talley et al., 2014). Although containerisation has brought logistics and transportation into a new stage (Lam and Gu, 2016), several features determine the operation mode and efficiency of the goods transportation and handling. We name some of those features: the amount, type, and quantity of delivered/handled products, and the infrastructure.

Because of globalization, the importance of ports' logistics and management grow. Indeed, the development of economic globalization led to an increase of intercontinental exchanges, stimulating the use of ports and shipping companies.

Europe has a population of roughly 510 million inhabitants and over 1,200 commercial ports (European Union, 2014). European

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ports constitute an entry to the continent, where 74% of international trade of goods in the EU circulate (MEMO/13/448 of the European Commission of 23 May 2013). They are also important for intra-European trade. The various European ports exhibit unbalanced levels of performance. Antwerp, Hamburg, and Rotterdam are the three largest European ports, trading one fifth of the goods arriving by sea to Europe. Therefore, there is a huge concern regarding making all the ports efficient. In fact, the current imbalance of European ports origins considerable inefficiencies and congestion levels, longer trips, larger costs, substantial traffic detours, and reduces the competitiveness.

The evaluation of port performance is a complex task, due to the diversity of variables and operations associated with a port, but also to the diversity of ports at global and European levels (Simões and Marques, 2010a). Literature on seaports' efficiency is very rich. Most of studies use nonparametric benchmarking methods to evaluate the performance of seaports all over the world. Although using this kind of methodologies is partially justified by their lack of major assumptions, when compared with the parametric ones – such as Stochastic Frontier Analysis (SFA) –, it should be remarked that both approaches have advantages, but also shortcomings and caveats.

Nevertheless, only few studies do measure the impact of potential explanatory dimensions on seaports' performance, which constitutes a major gap in literature. In fact, according to Tongzon and Heng (2005), the seaports' competitiveness and inherent performance result from diverse factors, including those that are beyond either managerial or authorities' control. Still, assessing the impact of the environment on the technical efficiency of players from any sector is compulsory for a good management of the available resources.

Chang and Tovar (2014), for instance, make a comprehensive literature survey on studies trying to explain inefficiency of port terminals by external drivers. A quick look on such a survey identifies some potential efficiency drivers, including ownership, port size, localization, capital intensity, type of organization, regulation status and changes, private sector participation, containerization rate, existence of oil refineries, demand variability, bulk rate, and occupancy rate, to name a few. However, to the best of our knowledge, no other study has analyzed the impact of the regional Gross Domestic Product (GDP), the water depth, the management model, some performance indicators, or the European directional division on European seaports' technical efficiency using the empirically-based benchmarking robust order-α method under data uncertainty. Hence, the present study complements the existing literature on testing the capacity of explanatory variables to clarify both efficiency distributions and efficient frontier shape.

This study aims to assess the impact of some explanatory variables on port performance, using robust but simple benchmarking methods, particularly the nonparametric output-oriented order-α model. Among the nonparametric methods, this one has the advantage of fixing a probability $1 - \alpha$ of observing seaports above the frontier, *i.e.*, super-efficient, thus potential outliers. In other words, the order-α model is less sensitive to outliers and extreme data, which is a serious problem of benchmarking methods enveloping the entire sample. As it will be explained further, the order-α model is extremely easy to implement and is very fast, because it uses matrixes manipulation rather than linear or mixed-integer linear programming tools. Using this method to estimate the association between (in)efficiency and exogenous dimensions is also extremely useful, as it does not rely on the separability condition (a common, still unrealistic, assumption of some second-stage procedures). Therefore, the order-α method disentangles the effect of the explanatory variables on the efficiency distribution from its effect on the efficient boundary.

Benchmarking exercises are sensitive to the data inaccuracy, which is not uncommon in the empirical word. Several approaches have been proposed to overcome such a problem, but they do not correctly model uncertainty/imperfect knowledge. In this case, we integrate the Stochastic multicriteria acceptability analysis (SMAA) with the output-oriented order-α model to obtain stochastic efficiency estimates, either conditional or not. Note that traditionally DEA and models alike (including the order-α) estimate deterministic efficiency scores. The proposed routine returns thousands bootstrap-like estimates that can be used to perform some statistical tests, which are useful to study whether an exogenous variable does impact on the efficiency boundary or distribution. This is innovative because SMAA was never applied to benchmarking exercises to model uncertainty.

After this introduction, the paper is organized as follows. Section 2 introduces the methodology to be used, Section 3 presents the case study, the results are provided and discussed in Section 4, and Section 5 draws the major conclusions and makes considerations about future research.

2. Methods

This study employs a novel nonparametric approach to investigate whether potential explanatory environmental variables truly impact on technical efficiency of seaports. One defines exogenous variables as those that may affect the production process but are not under management control. We also append some performance indicators into this category, although they are mostly directly controlled by managers but may impact on overall performance. All these variables may affect the boundary shape of the attainable set and/or the efficiency distributions (Badin et al., 2012), thus they are called 'explanatory variables' hereinafter.

Different nonparametric approaches have been used in the literature to measure such an impact. In general, two main shortcomings can be identified: first, efficiency scores computed using the most common benchmarking methods, like Data Envelopment Analysis (DEA), are serially correlated (Hirschberg and Lloyd, 2002); second, second-stage regressions based on unconditional efficiency estimates against external variables rely on the so-called separability condition (Daraio and Simar, 2007). The separability condition implies that the explanatory variables impact on efficiency distribution, but not on the efficient frontier shape – *i.e.*, seaports in the boundary are efficient regardless of the exogenous environment that they face. The double bootstrap (Simar and Wilson, 2007) is a widely employed approach to solve the serial correlation problem, but still relies on the separability condition; hence, coefficients from the multiple regression undertaken by this method are likely biased.

A more robust alternative is to use partial empirically-based frontiers, conditional to the external drivers (assumed as