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Investigating the drivers of railway performance: Evidence from selected Asian countries

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ABSTRACT

Although efficiency measurement has become relevant for logistics infrastructure planning, research on railway efficiency still remain scarce and rather focused on discussing rankings to the detriment of possible improvement paths. In fact, while the use of multi-activity models is increasing in railway efficiency research, previous studies fail short to assess their drivers at each operational stage. Here, we develop a novel super-efficiency Multi-activity Network DEA (MNDEA) model - based on directional distance functions (DDFs) and capable of handling undesirable outputs - to assess how different contextual variables impact railway efficiency levels in Asia. Two case studies are provided: one focused on six different countries, taken in aggregate (Japan, Thailand, Vietnam, Malaysia, Myanmar, and Indonesia). The other, on major state-owned Chinese railways. Differently from previous research, Generalized Additive Models for Location, Scale and Shape (GAMLSS) are used for the first time to regress super-efficiency scores on the contextual variable set. Findings reveal that the Asian railways are strongly marked by heterogeneity, the Chinese railways need to improve passenger-operation efficiency, while the other countries need to increase the cargo-operation efficiency. It also sheds lights on the design of policies for efficiency improvement in several different areas for the Asian railway system.

1. Introduction

Very often, productive structures may not only be characterized by a set of individual processes in displayed in series, but also each one of these processes may be composed by individual stages or activities that share common productive resources. While the computation of technical efficiency levels in such circumstances may impose additional modelling complexity, the derivation of improvement paths for each sub-structure may require a better understanding on how contextual variables may specifically impact on them. In fact, railway productive structure constitute an idiosyncratic case where passenger and cargo operations, which present different market dynamics, compete for the same source of productive resources such as tracks, wagons, and locomotives.

The industrial revolution brought profound changes in transport systems. The steam engine (1765) introduced the rail system (Rodrigue, Comtois, & Slack, 2013). With the improvement of the engines, railways were developed worldwide over the last 150 years. The expansion of railroads reached its height in the 20th century, but remains in expansion. Twenty-six percent (233,000 km) of the railway network installed in the world (901,000 km) is located in Asia and Oceania. This is the region where there is the greatest intensity of traffic per kilometer of track (productivity). It handled 77% of the global demand of passengers, influenced by the Indian, Chinese and Japanese markets, and 35% of cargo demand in 2015 (UIC, 2015). High-speed technology is present mainly in Asia (75%) and Europe (24%). These figures denote the importance of the Asian region to the growth and development of the railway industry, which constitute the locus of our study.

Comparing to other transportation systems, the rail has advantages, such as high safety and capacity, reliability, low pollution and energy consumption. Therefore, the rail is very popular in the transportation industry of the world nowadays, especially in the highly populated countries (Loo, 2009; Mohri & Haghshenas, 2017). This is the case of Asian countries, where traffic congestion, consumption of pollutant

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fuels, and road crashes are very common due to super population altogether with insufficiency of resources. Meanwhile, they are also confronted the low and slowly growing railway transport modal share, especially for the South-east Asian countries (More details can be found at www.openrailwaymap.org). Among all the Asian countries, four countries, including Japan, Korea, Indian and China have the most intensive railway transportation network. Moreover, China and Japan also built up high-speed rail lines during recent years. China (67 212 km) and India (66 030) has the longest railway lines there, which are mainly owned and controlled by the State as it requires a large amount of investments.

This research is motivated by several reasons. First of all, not only there are scarce studies on railway efficiency of fast growing Asian countries (Brooks & Hummels, 2005; Cheng & Lu, 2017; Hilmola, 2007; Jitsuzumi & Nakamura, 2010; Shi, Hoon Lim, & Chi, 2011; Tsai, Mulley, & Merkert, 2015; Utsunomiya & Hodota, 2011; Yamamoto & Talvitie, 2011), but also this transportation mode is relatively understudied when compared to ports and airports (Banos-Pino, Fernández-Blanco, & Rodríguez-Álvarez, 2002; Boardman, Laurin, Moore, & Vining, 2013; Cantos & Maudos, 2001; Cantos, Pastor, & Serrano, 2012; Jensen & Stelling, 2007; Jitsuzumi & Nakamura, 2010; Kumbhakar, 1989; Parisio, 1999; Yu, 2008; Yu & Lin, 2008). Second, this paper includes almost all relevant 'Asian Tigers', besides Japan and China with the exception of India (Lakhera, 2016), thus providing an unique overview on the railway best practices in Asia, despite the huge territorial and economic differences that exist among these countries. Third, most railway efficiency studies are focused on discussing rankings, rather than on proposing improvement paths based on exogenous (endogenous) variables related to the operational context that may act as drivers of superior or inferior performance levels (or their bounding factors).

Therefore, this research is focused on adding to the current literature by analyzing railway performance in Asia, based on selected country evidence from two case studies. In the first case study, 18 state-owned Chinese railways are analyzed from 2005-2013. In the second case study, railway production from six different Asian countries - Japan, Thailand, Vietnam, Malaysia, Myanmar, and Indonesia – are taken in aggregate from 2004-2014. Besides, we depart from the seminal idea of a MNDEA model as proposed by Beasley (1995) and Tsai and Molinero (2002) to analyze the role of cargo operation, passenger operation, and revenue generation – and their respective drivers - in the overall efficiency of the railway industry in Asia. A novel super-efficiency MNDEA model is developed here. Super-efficiency scores in DEA are not limited to one, hence, they present better discriminatory power than conventional scores bounded between 0 and 1, avoiding the existence of several efficient firms at the frontier of best practices. Not only it allows the treatment of railway accidents as an undesirable output during the revenue generation process, but it also adopts a DDF so that different outputs and inputs within the ambit of distinct railway activities may present different improvement rates.

Another distinctive feature of this paper is the use of GAMLSS regression models to predict the impact of contextual variables on super-efficiency scores. They were introduced as way to resolve the limitations of previous modelling approaches such as GLM (Nelder & Wedderburn, 1972) and GAM (Hastie & Tibshirani, 1990). In GAMLSS, it uses a very general distribution family and includes highly skew and/or kurtotic distributions, which is adequate to represent the asymmetrical outcomes of super-efficiency scores around one, replaces the exponential family distribution assumption. GAMLSS also allows the premise of independent observations of efficiency scores in light of contextual variables, which is adequate to DEA models since efficiency scores are obtained one at a time. The rest of the manuscript is structured in five more sections. Section 2 discusses the previous researches, while Section 3 focusses on the methodology. Both case studies are depicted in Sections 4 and 5. Conclusions and policy implications are presented in Section 6.

2. Literature review

There have been some studies in literature involving the efficiency frontier analysis of the railway transport systems of cargo and passengers between 2000 and 2016. Broadly speaking, two alternative methods have been used to analyze efficiency in railways. Parametric ones, such as the stochastic frontier approach (Banos-Pino et al., 2002; Coelli & Perelman, 1999; Jensen & Stelling, 2007; Loizides & Tsionas, 2002; Wang & Liao, 2006) and non-parametric ones, like DEA and its variants (Graham, 2008; Jitsuzumi & Nakamura, 2010; Liu et al., 2017; Yu, 2008; Yu & Lin, 2008).

Researches that used parametric methods tend to be much less numerous. A handful of studies, such as Couto and Graham (2009) used Stochastic Frontier Analysis (SFA) and cost-based SFA. These authors analyzed the efficiency of the European rail transport industry. Couto and Graham (2009) found that inefficiencies can essentially be explained by the excess capacity in the supply and by the over-employment of labor when using the EU railway data. Kumbhakar, Orea, Rodríguez-Álvarez, and Tsionas (2007) used Latent Class Model (LCM) and panel data of 17 European railroads. Crafts, Mills, and Mulatu (2007) used TFP (Total Factor Productivity) to estimate the efficiency levels of British railways. Crafts, Leunig, and Mulatu (2008) used TFP to assess whether the British railways were properly administrated in the beginning of the 20th century. Graham (2008) compared the results of efficiency measures with DEA and TFP.

On the other hand, in spite of the limitations of assuming uniform variations in the input/output vector so that efficiency levels can be increased, DEA is still the preferred method in railway studies. Authors like Bil (2013), Hilmola (2007) and Bhanot and Singh (2014) used the DEA model. Bil (2013) also assessed the over-estimation of the scores by a Slack Based Measure (SBM) model. George and Rangaraj (2008) used the DEA and Super-efficiency DEA (SDEA) methodologies to assess the efficiency of the railway areas of the network in India. Jitsuzumi and Nakamura (2010) used DEA and the cost-based efficiency model suggested by Farrell (1957) and Debreu (1951) to study the roots of lower efficiency levels of the Japanese railways. Differently from these previous studies, however, Oum, Pathomsiri, and Yoshida (2013) used Directional Output Distance Friction method to analyze the performance of distinct DMUs, thus overcoming the strong assumption of uniform improvement in inputs/outputs.

Only more recently papers started focusing on the impact of exogenous (regulatory issues, railroad location, type of cargo etc) and endogenous (economic conditions of the country, subsidy level, etc) on efficiency levels (Marchetti & Wanke, 2017). Boardman et al. (2013) employed data during the period of 1990–2011 to compare the efficiency change for the national railway privatization in Canada. Cantos et al. (2012) analyzed the impact of European reforms on railways from 2001 to 2008. Jitsuzumi and Nakamura (2010) analyzed inefficiency in Japanese railways and propose a model to compute subsidies. Bogart (2010) analyzed how ownership impact railway efficiency levels over the last century. Wanke and Barros (2015) analyzed the impact of the type of cargo, the railroad location and the travel time on efficiency and slack drivers in 12 cargo Brazilian railways.

Eventually, these analyses adopted some multivariate statistical method to regress efficiency scores into the set of contextual variables after computing the efficiency scores with some sort of DEA model first. For instance, Mallikarjun, Lewis, and Sexton (2014) applied in a second stage the Censored Tobit Regressions and Generalized Least Squares (GLS) with bootstrapping. Kabasakal, Kutlar, and Sarikaya (2015) also used a panel meta-regression in a second stage. Hilmola (2011) used a DEA model and linear regression in a second stage. Kutlar, Kabasakal, and Sarikaya (2013) employed the DEA model and Tobit Regression to regress efficiency scores onto most relevant outputs. Wanke and Barros (2015) used the Distance Friction Minimization (DFM) model and by Tobit regression investigated the effects of contextual variables on the Brazilian rail transport efficiency scores. Tsai et al. (2015) found that