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Spillovers, path dependence and the productive performance of European transportation sectors in the presence of technology heterogeneity

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ABSTRACT

Adopting a metafrontier framework and a second stage system GMM estimation procedure, the technology isolation assumption is relaxed and the role of technological spillovers and path dependence on the productive performance of Air, Land and Water transportation industries of seventeen European countries for the period 1999–2006 is explored. Our main findings suggest that path dependence is a major determinant of the productive performance of the European transportation systems while the technological spillovers are in full operation when the technological advancements are taken into account. Grounded in the empirical results, divergence and clustering processes are sketched out in the productive performance of European transportation systems.

1. Introduction

Technology homogeneity has always been a very crucial precondition in efficiency and productivity analysis and the transportation sector is not an exception. Engineers, economists, operational researchers, and scholars from the management disciplines who have been engaged in this line of research are always very cautious to ensure that decision making units (DMUs) are benchmarked against rivals who employ almost identical production technology. Although technology homogeneity is not a very clear situation, since "*heterogeneity of several types is everywhere*" (O'Donnell et al., 2006; Dosi et al., 2010), the urge to ensure as much technology homogeneity as possible, may result in a peculiar type of "*technological isolation*" of the examined DMUs. Technological isolation may be defined as the situation where even close neighboring, in technological terms, production units are considered as completely distinct and no technological flows, the so-called technological spillovers, between them are taken into account. In the case where technological isolation is not imposed during productive efficiency analysis—and hence technological spillovers are allowed to exist—the role of general purpose technologies, technological modularity, lumpiness and non-irreversibility, idiosyncrasies, absorptive capacity and network effects may be explored (Syverson, 2011). On the other hand, previous studies which acknowledge the existence of technological inter-linkages and inter-industry flows focus either on specific types of flows which may arise from R&D activities (Cainelli and Iacobucci, 2012; Del Bo, 2013), or those which are closely attached to factors related to the spatial or cognitive distance distribution of production entities, as the different types of variety (e.g. Frenken et al., 2007; Del Bo, 2013) or breadth and relatedness of technological linkages associated to international trade (Boschma and Iammarino, 2009). None of these studies however explicitly consider the possible bidirectional nature of effects, distinguishing between the source and the target of technological and knowledge flows.

A decade ago, Battese et al. (2004) introduced the notion of the metafrontier, which allows technological heterogeneity to be incorporated in productive efficiency analysis and therefore relax restrictive technological isolation conditions. In the framework of technological heterogeneity any positive influence of technological spillovers onto productive performance may be completely eliminated, if the production units are locked-in, or in other words if they exhibit path-dependence of the evolution of their productive performance. Regarding path dependence, the major arguments are that the accumulated competencies, capabilities and irreversible structures, more or less the full operational process of a firm as well as a number of contingent and localized conditions that exert significant effects on the non-ergodic dynamics of the process and change its path, its speed and its duration (Antonelli, 2008). Although within the evolutionary economics strand, the path dependence phenomenon is a cornerstone of the investigation of productive performance (David, 1993, 2001), the interdependence between neighboring technologies is a rather neglected issue.

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In this paper we introduce a theoretical and methodological framework which allows the co-examination of (i) technology heterogeneity, (ii) any inter-linkages and flows between the heterogeneous technologies, incorporating a plethora of differentials, observed or not as well as the multidirectional nature of such kind of flows and (iii) the path dependence of productive performance. This analytical framework is applied to three European transportation subsectors revealing interesting patterns of productive performance which have not been traced by previous seminal papers on transportation efficiency (Brons et al., 2005).

The European Commission has during the last 25 years or so actively established a number of initiatives/bodies aimed directly at fostering Europe-wide transport sector integration and development.[2] In 2011 a White Paper was released by the European Commission (2011) setting out a roadmap towards a 'single European transport area' by 2020, one which has the underpinnings of a 'competitive and resource-efficient transport system'. In this line, the issues of technological spillovers and path dependence are of primary importance in the case of European transportation sector, where policies are increasingly aimed at supporting EU wide convergence/cohesion in the transport sectors across the European members States.

In this work *we distinguish between Air, Land and Water Transportation Systems, contrary to previous studies which focus only on niches of these transportation systems, we allow for spillover effects among these industry-specific technologies while at the same time we test for path dependent regimes of their productive efficiency*. Relationships between the efficiency of transportation-industry specific frontiers and a unified transportation meta-frontier, enveloping them all together, can be a conceptually challenging notion.

The productive capacity and efficiency of all parts of the transport industry embed a much wider range of attributes and characteristics which lay behind how they are used. These may include general purpose technologies, with IT infrastructures being the most prominent, quality of human resources which are pumped from the same labor markets, safety and environmental regulations, financial schemes, managerial competencies and capabilities, operational procedures, institutions, etc. All of these may be considered as nodes of the transportation system network and links of the corresponding value chain. As a result, *severe questions are posed on the validity of the technological isolation hypothesis in the transportation sector case. Subsequently, the necessity to evaluate the performance of transportation systems in a technology heterogeneity framework becomes apparent*. On the other hand, *given the heavy infrastructure requirements of transport industries, path dependencies may arise due to slow adjustments and therefore narrow the influence of the any spillovers. Arguably path dependency is more likely to exist in transport than many other sectors due to the heavy infrastructure*.

In this paper we employ a unique panel dataset for the Air, Land and Water Transportation industries from seventeen European Countries covering the period from 1999 to 2006. A two stage analysis is followed. In the first stage we estimate—employing bootstrapped Data Envelopment Analysis (DEA)—productive efficiency both with respect to transportation industry-specific technologies and the European transportation metatechnology. In the second stage we employ the system GMM procedure in order to test for technological spillovers between the three industry-specific transport technologies, the European transportation metatechnology, and simultaneously for the influence of any path dependence regime on the productive performance of the European transportation industries. An additional feature of our approach is that we distinguish the spillover effects in to two types: 'outgoing', which are those generated from the individual frontiers moving towards the European transportation metatechnology and form the localized technical change; and 'incoming' ones, which represent the technological advancements generated from the best practices in the metatechnology being diffused towards the individual frontiers. Moreover, tracing technological spillovers and path dependence of European transport industries allows the sketching of "catching up" or "falling behind" phenomena, and the identification of their drivers, within and between transportation technologies in terms of performance.

The paper is ordered as follows: the next section discusses related literature; Section 3 outlines the theoretical and methodological framework introduced and applied in this paper, Section 4 presents the data; results and discussion are given in Section 5; Section 6 concludes the paper.

2. Review of the literature

Efficiency analysis is a widely used tool in transport. Regulators and other transport network analysts use efficiency analysis tools most often for the purpose of benchmarking the operational cost efficiency of public transport operators (see for example Holvad et al., 2004; Farsi et al., 2005; Margari et al., 2007 among others), with a view to providing information relevant to passenger fare-setting decisions. Brons et al. (2005) conducted a meta-analysis reviewing a large number of efficiency studies prior to 2005, highlighting among other things that two thirds of studies focused on productive efficiency, rather than their dual problem of cost efficiency. Their meta-analysis includes only 30 studies, suggesting that the area has attracted reasonable levels of research attention, but there probably remain opportunities to further contribute to our understanding.

The existing studies have generally evaluated productive efficiency for a specific mode of transport such as: water/sea ports (Cullinane et al., 2005; Cullinane et al., 2006; González and Trujillo, 2009; Odeck and Bråthen, 2012; Baired and Rother, 2013), urban transit systems (Holvad et al., 2004; García-Sánchez, 2009; Pinna and Torres, 2001; Margari et al., 2007; Roy and Yvrande-Billon, 2007; Karlaftis and Tsamboulas, 2012); airports (Adler and Golany, 2001; Martín and Roman, 2001; Merkert and O'Fee, 2013); or railways (Cantos and Maudos, 2001; Growitsch and Wetzel, 2009). The technological isolation assumption has been adopted, explicitly or implicitly, by all of the abovementioned studies which focus on specific segments (modes/niches) of the transportation industry and do not attempt to account for any interaction between transportation technologies or for possible path dependence regimes.

There is a smaller number of studies considering more than one area of the transportation industry at the same time, such as that of Koroneos and Nanaki (2008) who conduct an energy/exergy efficiency analysis of the Greek highway, railway, marine and civil aviation sectors, indicating that road transport is the most efficient. In the same line, Krautzberger and Wetzel (2012) jointly consider productivity growth along with environmental protection targets for four subsectors of the transportation industry (Land, Water, Air transport and also supporting and auxiliary activities) for the EU-27 and Norway for the period 1995–2006. However, neither of these studies take a clear account of the potential inter-industry spillovers from one transport sector to another, nor examining the path dependence of their productive performance. Unlike the previous studies, Del Bo (2013) explores the intra- (horizontal) and inter- (vertical) industry spillovers which are reinforced by foreign direct investment effects but without considering the role of technology gap. Additional developments focus on the sources of inefficiency in transportation activities (Albalate and Bel, 2010) and on the role of incomplete contracts.

The quantitative tools used to model efficiency historically are either parametric, such as Stochastic Frontier Analysis (SFA) or non-parametric via the Data Envelopment Analysis (DEA) technique. Brons et al. (2005) offer a broad overview of the methodologies in efficiency analysis while Karlaftis and Tsamboulas (2012) using a wide range of methodologies (DEA, SFA, neural networks) conclude that efficiency

[2] Indicatively one could mention the Trans-European Transport Network initiative (TEN-T) adopted in 1996 and the Innovation & Networks Executive Agency (INEA) established by the European Commission in 2014.

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