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The effect of high-speed technology on European railway productivity growth

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ABSTRACT

This paper examines European railway productivity growth by accounting for the variation of the attributes of output characteristics and the service quality that is supplied. Furthermore, this study uses the derived theoretical expressions of embodied technological progress to isolate the effects of high-speed technology on productivity growth using data that relate to European rail systems during the period from 1972 to 1999. The derived model shows that railway productivity improvements are especially relevant with regard to the output performance, with a mean value of 2.7% for the rate at which all outputs can grow over time with inputs held constant, rather than to input usage productivity improvements, with a mean value of 1.7% for the rate at which all inputs can be decreased over time with outputs held constant. Moreover, the results show that conventional high-speed technology, which allowed for an average increase in productivity growth of around 0.8%, has a larger effect on productivity growth than tilting train technology.

1. Introduction

Conceptually, productivity is a measure of firm production performance based on the rate at which inputs are transformed into outputs; in other words, productivity is the measure of the amount of output that can be produced per unit of input. Despite this basic idea of productivity viewed as a ratio between an organisation's outputs and its inputs, its measurement for comparison over time and/or across firms or industries involves various concepts and approaches. Diewert (1992) surveys alternative concepts and approaches of productivity measurement. He shows that there is significant variety in the concepts and approaches that are used, and this variety increases the complexity of conducting comparative analyses of the results from different studies.

Both the concept of productivity and the appropriate way to measure it are influenced by the purposes for which productivity is being measured. Oum et al. (1992) identifies a list of reasons that productivity should be measured; all of these reasons share a common desire to measure performance. According to their list, three classes of purposes are grouped according to their objectives and measurement approaches. These classes of productivity purposes are associated with three distinct measures of productivity: partial factor productivity, total factor productivity (TFP), and productivity growth (technological progress).

Partial productivity measures, such as labour productivity, are appropriate where disaggregate operational performance is of interest but generally are not very useful for railway industry comparisons, which explains why this approach has not been currently preferred in literature. Total factor productivity is the appropriate concept for most productivity measures when the purpose is to make comparisons across firms and/or over time, assessing pricing policies and public policy questions. However, TFP itself, as a gross measure of productivity including gains from all sources, covers different concepts and consequently it is more appropriate for pricing questions than public policy questions. Examples of single partial productivity applied to railway industry are presented in Nash (1985) and Tretheway et al. (1997).

When the purpose of productivity measurement is related to public policy issues, the use of the shift concept of productivity growth is more appropriate. This concept is associated with measures of productivity gains derived from fundamental changes in technology and requires the statistical estimation of production or cost functions, or the decomposition regression of TFP. Improved ability to identify shifts in productive abilities as distinct from other productivity sources has been a major focus of empirical studies of productivity. However, due to differences in cost/production function formulations and estimation models, previous results show great variety among studies and the main conclusion which can be taken is that the values resultant from these measures of productivity are generally below those of TFP. Recent examples of railway industry studies using TFP are Coelli and Perelman (2000), Sánchez and Villarroya (2000), Baños-Pino et al. (2002), Smith (2006) and Wang and Liao (2006).

When comparing productivity, whether the comparison is between firms, industries, countries or over time within firms, it is important to understand the sources of productivity in addition to obtaining knowledge about gross productivity measures, since,

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any comparison, to be accurate, must be performed in relation to a similar base. A decomposition of productivity is relevant in separating productivity gains that are one time improvements, as that of elimination of inefficiencies, from gains through shifts in productivity or those due to industry structure issues for instance from scale economies.

Thus, when decomposing productivity into sources, the measurement of productivity gains from exploitation of economies of scale has been a theme analysed by many authors. The knowledge of the existence of these economies could have important public policy implications such as in supporting parallel and/or end-to-end mergers, or supporting institutional restructuring process toward an internal contestable market versus a natural monopoly. Examples of these analysis applied to European railways are presented in Preston (1994), Andrikopoulos and Loizides (1998) and Sánchez and Villarroya (2000).

Empirical studies of productivity also separate productivity gains from eliminating existing inefficiencies, particularly when the aim of research involves policy changes analyses such as deregulation, privatisation, or change in regulatory technique. There are two types of inefficiencies: technical inefficiency (excess usage of inputs to produce outputs) and allocative inefficiency (wrong combination of inputs to produce output). Recent research has extensively been concerned with allocative and technical inefficiency measurement. However, the different studies produced highly dissimilar results, which lead to the conclusion that accurate measurement of efficiency is very sensitive to good quality data and model specifications, although this type of research could give a primarily finding on good and bad management and/or transport regulatory policies. Among several studies focused on railway inefficiencies, recent research using European data are those presented by Cantos and Maudos (2001), Christopoulos et al. (2001) and Lan and Lin (2006).

Despite the importance of the quantification of productivity sources and the related implication of policy implementation changes towards the improvement of productive efficiency, few studies have directly analysed the effect of specific technological innovations on productivity growth.

The technological progress that represents innovation and technical developments is a continuous source of productivity and could be, through its effect on the quality of service supplied (characterised by, for example, travel time savings, higher frequency of service, more comfortable and fashionable trains and modern stations), a crucial factor related to the increase of railway transport demand. For example, according to Button (1993), empirical studies indicate that public transport demand is sensitive to changes in service quality, especially to any reduction in the speed or frequency of services; this statistic reflects the decreased importance that is attached to the purely monetary dimension.

European railway transport innovation has been essentially characterised by high-speed technology, which has significantly contributed to the increase of the quality of service that can be supplied. Thus, it seems crucial to analyse the effect of service quality on productivity growth that is characterised by embodied technological progress beyond the usual analysis of productivity growth that is characterised by disembodied technological progress and measured through the time trend variable.

Fowkes and Nash (1991) discuss the journey time elasticity values of previous studies as follows: "... there was some sign (...) that traffic increased by a certain amount when the high speed train was introduced regardless of the extent of time saving produced; conversely the increase in traffic was found to be less in the small number of cases where a major speed improvement had been introduced without new rolling stock". Thus, following this impression and being certain of the primary importance of the increased demand resulting from service quality, as analysed by Couto and Graham (2008), one aims to analyse the effect on productivity that is generated by the utilisation of high-speed technology, which currently represents the most relevant contribution to the improvement of service quality.

The influence of high-speed technology on costs and productivity were analysed by Couto and Graham (2009) based on the elasticity results that were associated with the high-speed variables that were introduced in the estimated cost functions. However, any conclusions regarding high-speed effects on railway productivity are incomplete if cost analysis is the only object of study. To obtain more accurate knowledge regarding this effect, we must ensure that our embodied technological progress analysis incorporates the effects of the improvement of service quality on demand and costs.

Thus, in this paper, by considering the estimation of Couto and Graham (2008, 2009) with regard to the cost and aggregated rail demand function, one will re-evaluate productivity growth by accounting for the explicit relations and complementarities among the operational characteristics, the high-speed attribute effects, the demand response and the variable of cost.

Moreover, with the use of embodied technological progress theoretical expressions, it is possible to derive the hypothetical increments that are originated by high-speed technology and to consequently analyse the influence of this technology on productivity growth.

Thus, this paper has two main goals: the first one is to evaluate the productivity growth viewed as embodied technological progress. The second one is to predict productivity gains from high-speed technology usage.

Following the objectives described above, this chapter is organised as follows: in Section 2, it is derived the theoretical expressions that allow for the evaluation of productivity growth viewed as embodied technological progress. Section 3 describes and analyses the deterministic part of the cost and demand functions estimated by Couto and Graham (2008, 2009), respectively, because they are indispensable to the evaluation and analysis of the productivity growth of the European railways, which are presented in Section 4. Section 5 examines the effect of high-speed technologies on productivity growth through the analysis of a hypothetical prediction of productivity gains from high-speed technology usage. Section 6 resumes the main conclusions of the analysis of the effects of high-speed technology on productivity.

2. Measurement of productivity growth: embodied technological progress

Productivity growth may be viewed in two ways: as the common rate at which all outputs can grow over time with inputs held constant (PGY) or as the common rate at which all inputs can be decreased over time with outputs held constant (PGX).

In econometric methods, since the first model proposed by Solow (1957), the conventional rate of productivity growth has been identified with the rate of technical progress. Thus, according to common practice, considering an estimated cost function, differentiation of this function with respect to time provides a direct estimate of productivity growth measured as follows:

$$\mathrm{PGX} = -(\partial \ln g^V/\partial t)/\left(1 - \sum_k (\partial \ln g^V/\partial \ln K_k)\right) \tag{1}$$

$$\mathrm{PGY} = -(\partial \ln g^V/\partial t)/\left(\sum_j (\partial \ln g^V/\partial \ln y_j)\right) \tag{2}$$