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Measurement of input-specific productivity growth with an application to the construction industry in Spain and Portugal

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ABSTRACT

Decision making in companies requires an assessment of the efficiency and productivity of individual inputs to provide insights into the scope for improvement of inputs' use. This paper estimates an input-specific Luenberger productivity growth indicator that can be decomposed to identify the contributions of input-specific technological change, technical efficiency change and scale efficiency change. These components for a specific input sum up to the aggregated indicators which are then compared with the traditional Luenberger indicator. The application focuses on panel data of Spanish and Portuguese construction firms over the period 2002–2011, accounting for three inputs: materials, labor and capital. The results show that aggregated productivity change and its components computed from the input-specific productivity indicator are different from those obtained using a traditional approach. The results also indicate that productivity change is negative for labor and capital for construction firms in both Spain and Portugal, while productivity change of materials is positive for Portugal and negative for Spain. Productivity decline is worse for capital in the Spanish construction firms, and for labor in Portugal.

1. Introduction

The measurement of firms' productivity growth has been extensively studied in the literature. Productivity analysis over time can provide valuable insights into the evolution of an industry and its degree of competitiveness. It is a useful tool to support the design of firm's strategies and government policies towards the improvement of industry performance over time.

A frequently employed approach in the literature to evaluate productivity change over time is the Malmquist productivity index, introduced by Caves et al. (1982) and enhanced by Färe et al. (1992). The Malmquist index is calculated using ratios of Shephard distance functions and can adopt either an input contraction or an output expansion perspective. For those cases requiring simultaneous adjustments of inputs and outputs or non-radial expansions or contractions, Chambers et al. (1996) proposed the use of directional distance functions to evaluate productivity change over time using the Luenberger productivity growth indicator.

More recently, Mahlberg and Sahoo (2011) developed an enhanced Luenberger indicator using directional slacks-based measures, as proposed by Fukuyama and Weber (2009). This indicator is based on non-radial distance functions, and has the advantage of accounting for the existences of slacks in a context where both input contractions and output expansions are considered. As it allows the estimation of productivity change associated to individual inputs, it provides input-specific estimates of productivity change. This approach has the advantage of providing insights into the contributions of individual inputs to productivity change. As input-specific productivity change measures are recent, only a few applications are reported in the literature (e.g., Skevas and Oude Lansink, 2014, which used a Luenberger indicator, and Oude Lansink and Ondersteijn, 2006, which used a Malmquist index). Nevertheless, input-specific efficiency is a topic well-established in the literature, with studies mostly applied to the agricultural sector (Oude Lansink and Silva, 2003; D'Haese et al., 2009; Oude Lansink et al., 2002; Oude Lansink and Bezlepkin, 2003).

This paper aims at analyzing changes in productivity of individual inputs within the Iberian construction industry over the past decade (2002–2011). For this purpose, we develop an input-specific Luenberger productivity growth indicator, estimated using a Russell-type measure in the context of directional distance functions, following Färe and Grosskopf (2010). This approach allows removing the slacks in all inputs for the estimation of the projection to the efficient frontier. The use of a multiplicative directional distance function model, with a directional vector specified as being equal to the input levels of the decision making unit (DMU) under evaluation, has the advantage of allowing the interpretation of the inefficiency component associated to each input as

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a proportional change to the original input levels. We propose a decomposition of the efficiency change component of the input-specific Luenberger indicator to obtain further information concerning the sources of input-specific productivity change.

To the best of our knowledge, this study is the first to apply the input-specific productivity growth indicator in the context of the construction industry. Previous research of construction industry assesses the productivity growth of all inputs simultaneously and relates to the use of the Malmquist index to evaluate productivity change in the construction firms in China (Xue et al., 2008) and Australia (Li and Liu, 2010). Using a growth accounting framework, Abdel-Wahab and Vogl (2011) compare productivity growth of the construction sectors in Germany, France, UK, USA and Japan, while Ruddock and Ruddock (2011) analyze construction industry in the UK. The study developed by Horta et al. (2013) compares the productivity change of the construction industry in three world regions (i.e. Asia, North America and Europe) using the Malmquist index. Given the limited attention devoted to productivity change in the construction industry, a study of input-specific productivity change in Iberian countries can contribute to the literature by widening the scope of knowledge concerning the evolution of this sector.

The construction industry plays a central role in the economy of Iberian countries. The sector accounts for 10% and 7% of the Gross Domestic Product in Spain and Portugal, respectively. As a consequence of the 2008 global economic crisis, the Portuguese and Spanish construction industries faced a period of downturn. This caused a slowdown of construction industry activity and the bankruptcy of many construction firms. Comparing to Portuguese construction firms, Spanish companies were more severely impacted by the crisis as reflected by the higher decrease in the relative output and employment of construction industry in this country. An in-depth evaluation of productivity change in the Iberian construction industry is particularly important to support firms in the definition of successful strategies in order to prosper in the long-run, boosting the Iberian economy.

The remainder of this paper is organized as follows. Section 2 describes the methodology used in this paper. Section 3 presents the empirical application, including the description of the data set and the discussion of the results. The last section concludes and points topics for future research.

2. Input-specific productivity growth in the directional distance function context

Input-specific productivity growth has its origins in the notion of sub-vector efficiency that dates back to the work of Färe et al. (1994a) that estimated technical efficiency measures for a subset of inputs rather than for the entire vector of inputs. The approach to input-specific productivity we develop in this paper is similar to the approach used by Oude Lansink and Ondersteijn (2006), Mahlberg and Sahoo (2011) and Skevas and Oude Lansink (2014). It is different from Oude Lansink and Ondersteijn (2006) and Mahlberg and Sahoo (2011) because our study applies a Russell-type measure in the directional distance function context following Färe and Grosskopf (2010), while the study of Oude Lansink and Ondersteijn (2006) is based on a Russell measure with a DEA model in the context of radial measures of technical efficiency, and the study of Mahlberg and Sahoo (2011) is based on the slacks-based measure of Fukuyama and Weber (2009) with a directional distance function model. Our approach also differs from Skevas and Oude Lansink (2014) as their approach is designed to account for undesirable factors and assumes weak disposability of some inputs. Our approach also differs from aforementioned works in the sense that we develop an extended decomposition of input-specific productivity growth accounting for scale efficiency change, and apply it to the construction industry of two European countries. Hence, our measure provides more information regarding the sources of input-specific productivity change.

We start from a production technology where we assume that inputs x_i^t $(i=1,\ldots,m)$ are used to produce outputs y_r^t $(r=1,\ldots,s)$ in year t. Adapting Färe and Grosskopf (2010) slacks-based measure of efficiency in the directional distance function context, the directional input distance function ($\vec{D}_{T^t}$) in year t seeks to reduce the use of inputs x_i^t:

$$\vec{D}_{T^t}(x_i^t, y_r^t; g_{xi}^t) = \sup\left\{\sum_{i=1}^{m}\beta_i : (x_i^t - \beta_i g_{xi}^t, y_r^t) \in P_t\right\} \tag{1}$$

where g_{xi}^t represents the component of the directional vector determining the direction in which input x_i^t can be scaled, β_i measures the degree of inefficiency at time t of input i, and P_t represents the production technology in time t that transforms inputs into outputs. The production technology is defined as

$$P_t = \left\{(x_i^t, y_r^t) : x_i^t \text{ can produce } y_r^t\right\} \tag{2}$$

Expression (1) seeks for the largest feasible contraction of inputs. The Russell type of model represented by expression (1) sums the input inefficiencies, thus accounting simultaneously for the contribution of all inputs. Therefore, the approach we use is a Russell type of measure in the directional distance function context, which removes all slacks in the inputs. This approach has some desirable properties that motivate its usage. First of all, the Russell type of measure represents a solution for the problem of nonzero slack in efficiency measurement using DEA. Therefore, it measures inefficiency taking into account all sources of inefficiency (including slacks). Also, it supports the notion of a Pareto–Koopmans inefficiency that equates the efficiency with belonging to the efficient subset, on the contrary to the Debreu–Farrell measures that require that efficient observations belong to the isoquant (Ferrier et al., 1994). Moreover, it allows measuring the inefficiency of particular inputs, which is not the case for the most widely used measure, i.e. the Debreu–Farrell measure.[1]

To compute input-specific productivity, four linear programming (LP) models have to be solved for two consecutive years using Data Envelopment Analysis (DEA): two single periods LP models and two cross-period LP models. All models assume constant returns to scale. The LP models used to evaluate a firm 0 in a sample with $j=1,\ldots,n$ firms are

$$\vec{D}_{T^t}(x_i^t, y_r^t; g_{xi}^t) = \max_{\beta_i^1,\lambda_j^1}\left(\sum_{i=1}^{m}\beta_i^1\right) \tag{3}$$

$$\text{s.t.} \sum_{j=1}^{n}\lambda_j^1 y_{rj}^t \geq y_{r0}^t, \quad r=1,\ldots,s$$

$$\sum_{j=1}^{n}\lambda_j^1 x_{ij}^t \leq x_{i0}^t - \beta_i^1 g_{xi}^t \quad i=1,\ldots,m$$

$$\vec{D}_{T^{t+1}}(x_i^t, y_r^t; g_{xi}^t) = \max_{\beta_i^2,\lambda_j^2}\left(\sum_{i=1}^{m}\beta_i^2\right) \tag{4}$$

[1] In the literature there is a theoretical debate on which efficiency measure should be used. Some authors favor the Russell measure, whereas others criticize it. Recently, Russell and Schworm (2011) posit four axioms that an ideal efficiency measure should satisfy and compare different efficiency indicators including Russell measure, analyzing whether they satisfy these properties. The conclusion is that none of the measures can satisfy all four conditions simultaneously and hence the trade-off exists in selecting among indexes.