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Productivity growth and biased technological change in hydroelectric dams

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ABSTRACT

This paper analyses productivity growth and the nature of technical change in a sample of Portuguese hydroelectric generating plants over the period 2001 to 2008. In a first step, we employ the Luenberger productivity indicator to estimate and decompose productivity change. A Malmquist productivity index is also used for a comparative purpose. The results paint a picture of mixed productivity performance in the Portuguese energy sector. The first decomposition underlines that, in average, the productivity variation is explained by the technological change. Then, in a second step, we analyse the nature of this technical change by using the recent concept of parallel neutrality (Briec et al., 2006). We observe a global shift in the best practice frontier as well as in the evidence of input bias in technical change.

1. Introduction

Efficiency at the level of the enterprise is a major issue in contemporary European economics, due to the ever more intense pressure that competition has exerted on prices since the adoption of the E.U.'s Single Market Programme (SMP). This was established in 1992 with the aim of facilitating the free movement of goods and services throughout the Member-States. In the energy industry, this competitive pressure has resulted in two stages of evolution: first, the deregulation of the former national markets (Kleit and Terrell, 2001); a second stage has seen an increase in competition, both internally and across borders, allowing for the entry of other national energy companies into what were formerly national markets. The changes observed in the market have obliged the energy companies to react, but strategic activity requires a sound, efficient basis if it is to yield successful results. Efficiency in energy has been analysed by Førsund and Kittelsen (1998), Edvardsen and Førsund (2003), Jamasb et al. (2004), Estache et al. (2004) and Farsi and Filippini (2004), Managi et al. (2004, 2005) and Nakano and Managi (2008) among others.

The present research is based on our observation of the various threats confronting the Portuguese energy sector at the present time. Among these, the growing number of major Spanish energy companies that have entered the Portuguese market as a result of the SMP has led to the above-mentioned competition with national players. This reveals the small dimension of most Portuguese energy companies, arising from the small size of the national market and the relatively low level of disposable income among Portuguese consumers. This small size restricts the possibility of expansion into the European market, as Portuguese energy producers lack the economies of scale that exist for larger enterprises, which can benefit from operating in several contiguous markets. However, in some but not all cases, the process of mergers and acquisitions has had the effect of increasing the size of energy companies through their purchase of larger shares of the market. Furthermore, a degree of saturation already exists in this energy market, implying that a continuing process of consolidation will serve to rationalise competition in the medium to long term, by removing the weaker players from the market. Another threat stems from the role played by the State and the policy that has prevailed in recent years. Despite the deregulation enforced by the E.U., the State is present in the market in the form of its holding of a golden share in the stock of EDP, which is the largest Portuguese energy company. This policy may restrict the growth of private companies, in addition to protecting EDP from acquisition by Spanish companies, which violates the spirit of the SMP. In addition, competition has been extended to the Iberian gas and liquid petroleum with the Portuguese EDP buying the Portugas and the Spanish Repsol buying the Royal Dutch Shell Portugal (gas and liquid petroleum) when this company abandoned the market in 2004. Finally, the regulatory agencies are suspected of collusion with EDP against producers and consumers, Barros and Peypoch (2007). This may result from the head regulatory agency named by the Ministry of Economy that ends up with close relationship with EDP and an apparent low authority towards the main energy company, derived from this company market share.

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This paper aims to analyse the efficiency of EDP Hydroelectric generating plants[1] within a new and original procedure. The directional distance function and the Luenberger productivity indicator are used to identify the efficient and productivity scores of each unit analysed. This investigation stems from a research carried out into an industry's best practices, based on the idea that the widespread application of these can lead to improved performance throughout the whole industry overcoming the above threats (Färe et al., 1983, 1985; Atkinson and Halvorsen, 1986; Pollitt, 1996). A survey of the existing literature can be found in Barros (2008). The paper is organised as follows: in Section 2, we explain the theoretical framework supporting the model used; in Section 3, we present the data and results; and finally, Section 4 is devoted to the discussion and conclusion.

2. Methodology

2.1. The Luenberger productivity indicator

Represent inputs by $x\in\mathbb{R}^n_+$ and outputs by $y\in\mathbb{R}^p_+$. The production set T_t is the set of all the input–output vectors $(x,y)\in\mathbb{R}^{n+p}_+$ such that

$$T_t = \left\{(x,y)\in\mathbb{R}^{n+p}_+ : x \text{ can produce } y \text{ at } t\right\}. \tag{2.1}$$

Let $L_t:\mathbb{R}^p_+\rightarrow 2^{\mathbb{R}^n_+}$ denote the input correspondence that maps all $y\in\mathbb{R}^p_+$ to input sets capable of producing them

$$L_t(y) = \{x\in\mathbb{R}^n_+ : (x,y)\in T_t\}. \tag{2.2}$$

The output correspondence $P_t:\mathbb{R}^n_+\rightarrow 2^{\mathbb{R}^p_+}$ maps all $x\in\mathbb{R}^n_+$ into sets of outputs that can be produced by those inputs:

$$P_t(x) = \{y\in\mathbb{R}^p_+ : (x,y)\in T_t\}. \tag{2.3}$$

We have

$$(x,y)\in T_t \Longleftrightarrow x\in L_t(y) \Longleftrightarrow y\in P_t(x). \tag{2.4}$$

For all vectors z,w in $\mathbb{R}^m$ we denote $z\leq w$ if $z_l\leq w_l$ for all $l=1\cdots m$. We impose standard properties on the technology:

T1: $(0,0)\in T_t$, $(0,y)\in T_t\Rightarrow y=0$ i.e., no fixed costs and no free lunch;
T2: the set $A(x)=\{(u,y)\in T_t : u\leq x\}$ of dominating observations is bounded $\forall x\in\mathbb{R}^n_+$, i.e., infinite outputs cannot be obtained from a finite input vector;
T3: T_t is closed;
T4: For all $(x,y)\in T_t$, and all $(u,v)\in\mathbb{R}^{n+p}_+$, we have $(x,-y)\leq(u,-v)\Rightarrow(u,v)\in T_t$ (free disposability of inputs and outputs);
T5: T_t is convex.

Assumptions T1–T5 imply that for all $(x,y)\in T_t$, the subsets $L_t(y)$ and $P_t(x)$ are closed, convex and satisfy free disposability.

The directional distance function $D_t:\mathbb{R}^{n+p}_+\times\mathbb{R}^{n+p}_+\rightarrow\mathbb{R}\cup\{-\infty\}\times\cup\{+\infty\}$ is defined by:

$$D_t(x,y;h,k) = \begin{cases} \sup\{\delta : (x-\delta h, y+\delta k)\in T_t\} & \text{if } (x-\delta h, y+\delta k)\in T_t \text{ for some } \delta\in\mathbb{R} \\ -\infty & \text{otherwise} \end{cases}$$

The definition implies $D_t(x,y;0)=+\infty$. However, the direction $g=(h,k)$ is fixed, and hence we suppose that $g\neq 0$. Detailed properties of the directional distance function can be found in Chambers et al. (1996, 1998).

The directional distance function is a function representation of the technology, namely

$$(x,y)\in T_t \Leftrightarrow D_t(x,y;g)\geq 0.$$

$D_t(\cdot\,;g)$ is also concave and continuous on the interior of $\mathbb{R}^{n+p}_+$.
If $h\neq 0$ and $k\neq 0$ then:

$$D_t(x,y;h,0)\geq 0 \Longleftrightarrow x\in L_t(y) \quad \text{and} \quad D_t(x,y;0,k)\geq 0 \Longleftrightarrow y\in P_t(x). \tag{2.5}$$

Following Chambers (1996) one can introduce a Luenberger productivity indicator to measure the productivity changes between two time periods. This Luenberger productivity indicator is defined by

$$L(x_t,y_t,x_{t+1},y_{t+1};g) = \frac{1}{2}\left[D_{t+1}(x_t,y_t;g)-D_{t+1}(x_{t+1},y_{t+1};g) + D_t(x_t,y_t;g)-D_t(x_{t+1},y_{t+1};g)\right]. \tag{2.6}$$

Positive growth (decline) is indicated by positive (negative) value. The Luenberger productivity indicator is additively decomposed as follows

$$L(x_t,y_t,x_{t+1},y_{t+1};g) = [D_t(x_t,y_t;g)-D_{t+1}(x_{t+1},y_{t+1};g)] + \frac{1}{2}\left[\left(D_{t+1}(x_{t+1},y_{t+1};g) - D_t(x_{t+1},y_{t+1};g)\right) + \left(D_{t+1}(x_t,y_t;g)-D_t(x_t,y_t;g)\right)\right], \tag{2.7}$$

where the first term (inside the first brackets) measures efficiency change between periods t and $t+1$. Hence, we denote:

$$EFFCH = D_t(x_t,y_t;g)-D_{t+1}(x_{t+1},y_{t+1};g). \tag{2.8}$$

The second term (inside the second brackets) captures the technical change component and represents the shift of technology between periods t and $t+1$. Thus, technical change is denoted as:

$$TECH = \frac{1}{2}\left[\left(D_{t+1}(x_{t+1},y_{t+1};g)-D_t(x_{t+1},y_{t+1},g)\right) + \left(D_{t+1}(x_t,y_t,g)-D_t(x_t,y_t,g)\right)\right]. \tag{2.9}$$

This decomposition was proposed in Chambers (1996) and inspired from the decomposition of the Malmquist index in Färe et al. (1994). Fig. 1 shows the Luenberger productivity indicator.

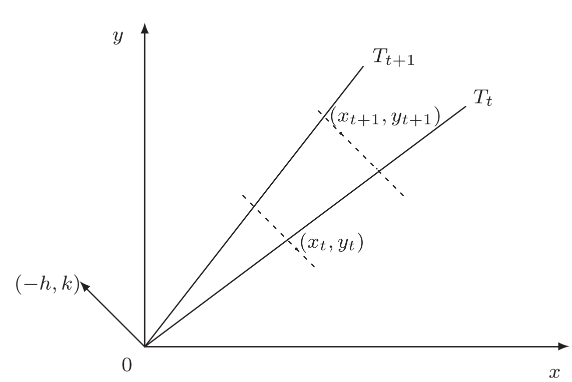

Fig. 1. Luenberger productivity indicator.

[1] See Barros and Peypoch (2007, 2008) for an efficiency analysis using alternative methods and Barros (2008) for a complete presentation of the contextual setting of the Portuguese energy sector.