Energy Policy 37 (2009) 4098–4103

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Bootstrapped efficiency measures of oil blocks in Angola

C.P. Barros, A. Assaf *

Victoria University, Centre for Tourism and Services Research, PO Box 14428 MCMC, Melbourne, Victoria 8001, Australia

ARTICLE INFO

Article history:
Received 6 April 2009
Accepted 4 May 2009
Available online 11 June 2009

Keywords:
Angola oil blocks
Technical efficiency
Policy implications

ABSTRACT

This paper investigates the technical efficiency of Angola oil blocks over the period 2002–2007. A double bootstrap data envelopment analysis (DEA) model is adopted composed in the first stage of a DEA–variable returns to scale (VRS) model and then followed in the second stage by a bootstrapped truncated regression. Results showed that on average, the technical efficiency has fluctuated over the period of study, but deep and ultradeep oil blocks have generally maintained a consistent efficiency level. Policy implications are derived.

1. Introduction

Oil production is a major concern in contemporary economies, facing the risk of reserve exhaustion (Tsoskounoglou et al., 2008; Höök and Aleklett, 2008; Karbassi et al., 2007; Managi et al., 2006). Recent years have also presented additional challenges, mainly due to the dramatic increases in oil related trade—a trend which is predicted to grow even more in the future, largely due to the rapid and strong growth of emerging economies such as China and India and the continuing, even rising dependence on fossil fuels for energy (Mohn and Osmundsen, 2008). Oil blocks are the parcels for exploration of oil, comprised of several oil fields, and generally sold by the owner, i.e. the government, as concessions to oil production companies. Each oil company explores one or more oil fields in the oil block. Therefore, oil blocks are units that are managed to extract the major amount of oil. From the Angolan government perspective, the management and high efficiency of oil blocks is of great interest, mainly because of the high dependence on oil revenue, where oil represents almost 90% of Angola tax receipts. The need to maintain a consistent performance is however challenged by several uncontrollable factors, mainly related to random fluctuations (price change or oil exhaustion) of oil extraction from oil blocks.

The performance measurement of oil blocks should therefore be considered as a main issue, and adequate management energy policy based on efficiency is needed to ensure high production and earnings (Kjärstad and Johnsson, 2009). Lessons can be learnt from productivity studies, as an efficiency score provides causes of why an inefficient oil block lags behind an efficient one, enabling therefore productivity enhancement policies. Focusing on the issues of efficiency changes and efficiency determinants, we aim in the present research to develop improvement policies for Angola oil blocks. A two-stage data envelopment analysis (DEA) double bootstrap model is adopted. In the first stage, we estimate a bootstrapped DEA–variable returns to scale (VRS) model, and in the second stage, we estimate a bootstrapped truncated regression to identify the sources of productivity differentials. The motivations for this research stem from the following considerations: First, with an economy dependent on oil exports, and giving the importance of oil at a national level, performance of Angola oil blocks is of high interest to the government of Angola and to oil companies exploring the blocks. It is surprising, however, that no research has yet been published on Angola oil blocks. Further motivations for this study relate to the need to improve the accuracy in the performance measurement of oil blocks. The traditional DEA models used in the energy literature have been under some criticisms where a small perturbation can result in different efficiency rankings (Ben-Tal and Nemirovski, 1998). On the other hand, the adoption of bootstrap procedures (Simar and Wilson, 2007) should enable more robust estimates. More details about of the bootstrap approach are provided in later sections of this paper.

The remainder of this paper is organised as follows. Section 2 presents the contextual setting. Section 3 details the methodology. Sections 4 and 5 present the data and results. Section 6 presents the discussions and implications, and Section 7 presents a summary of the main findings.

2. Contextual setting

Angola is a major African country relying on its richness in oil and diamonds. The country earned its independence in 1975 after a long Portuguese colonisation. However, soon after, the country

* Corresponding author. Tel.: +61 3 99194632; fax: +61 3 9919 4931.
E-mail address: albert.assaf@vu.edu.au (A. Assaf).

0301-4215/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enpol.2009.05.007

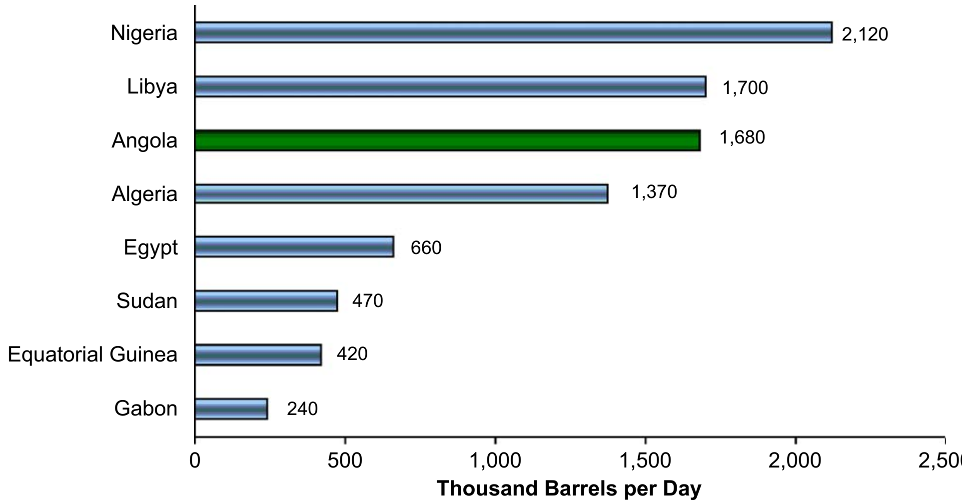

Fig. 1. Top African oil production, by Country, 2007, *Source*: EIA short-term energy.

entered in a period of costly civil war that only came to an end in 2002 (Ferreira and Barros, 1988). With the end of civil war, Angola was in a condition of macro-economic turmoil, with rising inflation and devalued national currency (the kwanza). The intervention of the International Monetary Fund (IMF) was reinforced in 2000 with the adoption of a macro-economic stabilization program that has recently started to achieve its aims.

The country is currently the world's second-largest producer of oil in Sub-Saharan Africa, after Nigeria. As indicated in Fig. 1, on the African stage, the country is also between the highest rank oil producers. In 2007, the production output rose to 1.68 million barrels per day, providing 91.94% of Angola's total export revenues. The last two years increase of oil prices has also provided further boost to the economy. However, with the recent sharp and unexpected drop in oil, the public budget might be sliced twice in 2009.

Some of the world's leading oil companies have a presence in Angola's oil blocks. Each oil block is a natural unit from which oil is extracted by various oil companies, often in partnership with the national company, Sonangol. Depending on the block's natural content, the technique adopted and managerial procedures, the blocks will have different oil fields producing different quantities of oil. Therefore, it is of value to analyse the performance of current of Angola's oil blocks, and highlight areas of potential improvements. Besides the blocks presently producing oil in Angola, several other oil fields are being investigated, but are not yet in production, see Table 1.

3. Methodology

3.1. Efficiency measurement

DEA is used in the first stage for estimating the technical efficiency of Angola oil blocks. The DEA approach usually (but not always) assumes that all firms, or more broadly, decision-making units (DMUs) within a sample have access to the same technology for the transformation of a vector of N inputs, denoted with x, into a vector of M outputs, denoted with y. This technology can be described by a set $T \subseteq R_+^N \times R_+^M$ as

$$\Psi = \{(x,y) \in \Re_+^N \times \Re_+^M : x \in \Re_+^N \text{ can produce } y \in \Re_+^M\} \quad (1)$$

This technology satisfies the following conventional assumptions:

A1: $(0,0) \in \psi_t, (0, y_t) \in \psi_t \Rightarrow y_t = 0$ i.e., no free lunch;
A2: the set $A(x_t) = (u_t, y_t) \in \psi_t; u_t \leqslant x_t$ of dominating observations is bounded $\forall x_t \in R_+^N$, i.e., infinite outputs are not allowed with a finite input vector;
A3: ψ_t is closed;
A4: $\forall (x_t, y_t) \in \psi_t, (x_t, -y_t) \leqslant (u_t, -v_t) \Rightarrow (u_t, v_t) \in \psi_t$, i.e., fewer outputs can always be produced with more inputs, and inversely (strong disposal of inputs and outputs);
A5: ψ_t is convex.

In the DEA context, the estimator of the production set $\hat{\Psi}$ is obtained using a linear programming methodology, as Ψ is not actually observed in practice. The motivation and early versions of DEA models have appeared in several previous studies in the literature, so they will not be reiterated here. For a detailed review refer to Coelli et al. (1998).

The production model used in this study follows an output-oriented assumption and can be derived for the ith firm by solving the following linear programming:

$$\hat{\delta}_i = \max_{\hat{\delta}_i, \lambda} \left\{ \delta > 0 \middle| \hat{\delta}_i y_i \leqslant \sum_{i=1}^{n} y_i \lambda; x_i \geqslant \sum_{i=1}^{n} x_i \lambda; \sum_{i=1}^{n} \lambda = 1; \lambda \geqslant 0 \right\}, i = 1 \dots n \text{ firms} \quad (2)$$

where λ is a $I \times 1$ vector of constants. The value of $\hat{\delta}_i$ obtained is the technical efficiency score for the ith firm. A measure of $\hat{\delta}_i = 1$ indicates that the firm is technically efficient, and inefficient if $\hat{\delta}_i > 1$. This linear programming problem must be solved n times, once for each firm in the sample. Note that the DEA model can also be estimated using either the constant returns to scale (CRS)[1] or variable returns to scale assumptions and the shape of the frontier will differ depending on the scale assumptions that underline the model. In this paper we rely on the VRS assumption, as the CRS is only correct as long as it is appropriate to assume that firms are operating at an optimal level of scale. Technological

[1] A production function is said to exhibit constant return to scale (CRS) if a proportionate increase in inputs results in the same proportionate increase in outputs. The variable return to scale (VRS), on the other hand, doe not assume full proportionality between the inputs and outputs.