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Examining the process of normalising the energy-efficiency targets for coal-based thermal power sector in India

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ABSTRACT

Setting targets and normalising them are two of the most important elements in the recently introduced market-based climate-change mitigation policy—Perform, Achieve, and Trade (PAT)—in India. The scheme permits, in the monitoring and verification phase, normalisation of the efficiency realisation against unfavourable working conditions. On the one hand, such normalisation brings the energy efficiencies of plants operating in different conditions to a common level, on the other hand, adjustments resulting from normalisation are likely to provide free-riding benefits, and in addition, results in alteration of efficiency realisation. This may be a source of distortion in the market expectation, resulting in trading phase uncertainties. This paper examines the effects of normalisation on the specific energy consumption in the context of the PAT scheme in the coal-based power sector. The paper makes a cross-sectional analysis involving data envelopment analysis and Tobit regression. The results indicate that effect of variation in system demand, planned maintenance time, forced outage, fuel quality, and fuel mix on specific energy consumption is substantial. However, the effect of the variability in coal quality and fuel mix is significantly higher than the other variables. Therefore, use of clean-coal is suggested to stabilise the specific energy consumption for a stable certificate market.

1. Introduction

Energy efficiency improvement is globally accepted as an approach to sustainable energy supply and emission reduction. In this context, market-based energy efficiency policies have gained popularity across many countries. India has recently introduced, under its climate-change mitigation policy, a market-based scheme—Perform, Achieve, and Trade (PAT)—to achieve energy efficiency in various sectors. As part of this scheme, a unit-wise reduction in specific energy consumption is envisaged by specifying plant-specific targets [4,7,24].

In order to take into account the effect of intra-sector diversity in operating conditions, the set targets are normalised with an objective of measuring energy efficiency in a level playing field. The most tricky part of this exercise is the ex ante determination of the explaining variables of the working conditions that are beyond the control of the plant management, since the outcome of the energy efficiency scheme can be greatly influenced by the normalisation mechanism [15,5]. In the present study, we examine, in the context of India's thermal power plants, whether the uncontrollable variables forming the criteria for normalisation have any influence on the plant performance, and, if so, to what extent such uncontrollable variables influence the energy efficiency of the plants.

Normalisation or correction of targets, ex-post, is a widely accepted feature in the market-based energy efficiency schemes. It is applied to ensure that a plant is not penalised for a condition, which is beyond its control [16,19,25]. It is possible that this facility may be misused by the plants. Since the process of normalisation offers an opportunity for adjustment of the targets, it is likely that the obligated plants may attribute the cause of the plants' non-conformance to the adverse working conditions, and seek correction in the targets within the normalisation framework. Furthermore, adjustment of efficiency realisation at a later stage is likely to distort the expected certificate entitlement, and therefore, may result in uncertain trading phase [17,6].

To guard against such a possibility, it is important that the variables forming the basis of normalisation should be uncontrollable (i.e., not influenced by managerial decisions) and should directly or indirectly influence a plant's energy efficiency. Considering the important role played by the market-based energy efficiency policies in ensuring energy security and emission reduction, we set our objective to examine the effect of normalising factors on the effectiveness of the PAT scheme.

In this context, we focus on two key issues associated with the process of normalisation in the PAT scheme in India:

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Table 1
Factors used in different studies for performance analysis.

Authors	Variables used for determining performance
Singh [30]	Capacity and Unit size
Sinha [31]	Plant design, Vintage, Plant location, Major equipment manufacturer and Operational pattern
Khanna and Zilberman [20]	Coal quality
Shukla et al. [28,29]	Fuel character, Choice of technology, Size, Vintage, Ownership pattern, Management pattern and Maintenance schedule.
Shanmugam and Kulshrestha [27]	Capital, Coal consumption, Oil consumption and Auxiliary power consumption
Sanpasertparnich and Aroonwilas [26]	Coal quality, Steam cycle efficiency
Yang and Pollitt [35]	Fuel quality, scale of operation
Yu et al. [36]	Weather condition
Bajpai and Singh [2]	Coal and oil consumption, Auxiliary power consumption, Installed capacity and Operational time

(1) Do the normalising factors of the PAT normalisation mechanism have any significant influence over energy efficiencies of Indian coal-based thermal power plants?
(2) To what extent each of these factors influences the efficiency of coal-based thermal power plants?

We have examined energy efficiency and environmental performance of 69 coal-based thermal power plants in India, which are obligated under the PAT scheme to improve energy efficiency. Data Envelopment Analysis (DEA) and Tobit regression are applied to examine the effect of uncontrollable variables used for normalisation on the plant performance. The outcome of the study indicates that:

1. Five of the six normalising variables have a significant influence on the energy efficiency of the plants, the coal quality, grid operating conditions and the fuel mix being the most dominant.
2. The fuel supply reliability does not have any significant influence on the energy efficiency.

While the first result implies that normalising the efficiency targets is rational in the context of variability in operating conditions in India. The second result, however, clearly points to a possibility that under the present normalisation criteria of the PAT scheme, an inefficient plant may get its heat rate adjusted against fuel supply constraint and earn certificates—a free riding benefit—even though the fuel supply has very little impact on heat rate.

The remainder of this paper unfolds as follows: Section 2 makes a survey of literature on normalisation in energy efficiency certificate schemes, variables affecting the specific energy consumption, and on the application of DEA in estimating the effect of the uncontrollable variable. Section 3 presents the theoretical background, target setting, and normalisation mechanism, and the research questions raised. Section 4 formulates the DEA model, describes the Tobit regression model for estimating the effect of uncontrollable normalisation variable. The ways of selecting and collecting data for applying them to the models are presented in Section 5. Section 6 analyzes the results obtained from the models in the case of the coal-based thermal power sector in India, and Section 7 concludes the paper and indicates the scope of future work in this area.

2. Literature review

2.1. Normalisation and energy efficiency schemes

Normalising the targets for any temporal and spatial diversity of variables affecting efficiency is a common feature in market-based energy efficiency schemes [25]. For example, in Italian energy efficiency scheme, the baseline energy savings stipulated on the basis of technical evaluation is adjusted using a default factor. Similarly, in the UK, the baseline efficiency is standardized considering the technology used and fuel type [16]. However, normalisation or standardization of efficiency realisation during monitoring and verification phase alters the market expectations because the adjustments made through normalisation distorts the outcome of the tradable efficiency scheme [17,6]. Therefore, for a credible energy efficiency scheme and predictable certificate market, the normalisation mechanism should be designed in such a manner that normalisation should not result in substantial alteration of expected efficiency realisation.

In the PAT scheme of India, the target is normalised in the assessment year on the basis of a set of criteria specifying the operating conditions and fuel quality [5,7]. The scheme recognizes five normalisation factors [15,5]. They are the quality of fuel, fuel mix, fuel availability, breakdown, and unscheduled outage. In order to justify the selection of the normalisation factors, it is crucial to understand the causal relation between these factors and the plant performance. A number of studies reported in the past have each identified different sets of factors that influence the energy efficiency of thermal power plants. Table 1 gives the set of factors identified by these studies

These studies, no doubt, have made a significant contribution to the specific area of power plant performance, but there has not been any study that divides the influencing factors into two sets of controllable and uncontrollable factors and separately finds their effect on plant performance.

Regression analysis [30,31], simulation study [22,26], and DEA [2] are the most popular methodologies applied to examine the effect of different variables on the performance. However, DEA combined with censored regression is widely applied to examine the effect of uncontrollable variables on the efficiency [12,18,35,36].

While the studies by Yang and Pollitt [35] focused on power plant performance, Yu et al. [36] examined the effect of weather conditions on the performance efficiency of electrical transmission and distribution systems in the UK. The studies by Hu et al. [18] examined the effect of external environment on the regional energy efficiency of 23 regions in Taiwan and Fang et al. [12] examined how the energy efficiency and energy saving targets are affected by the characteristics of different service sectors.

The common feature of the above-stated studies is that they applied DEA for efficiency analysis and regression method for examining the effect of the uncontrollable variables. This combined method has been found to provide reliable insights, since it leverages the strength of DEA in handling multiple inputs and outputs, and the robustness of regression method in establishing the relation of (in)efficiencies with the uncontrollable variables [10,35]. The present study has used this combination approach of DEA and regression analysis to examine the effect of normalisation variables on plant performance.

2.2. Efficiency estimation and uncontrollable variable using DEA

Charnes et al. [9] was the first to propose DEA as a non-parametric method of performance analysis. Its application in the performance study of the power sector has been extensive [38].

To incorporate the effect of uncontrollable variables on performance, four variations in the basic DEA model have been proposed. They are the one-, two-, three- and four-stage models. In the one-stage