Chapter 6

Discussion

A key component of the energy policy in different countries has been increasing energy efficiency and productivity, thereby guaranteeing sustainable development. In this context, researchers have developed indicators to measure and evaluate the development and outlook of energy efficiency performance within economic sectors or across countries or regions.

Improving energy efficiency has become an important element of different perspectives that guarantee consumption and sustainability as key elements of economic development. The main objectives for improving energy efficiency on a macroeconomic level are to maintain reserves of fossil fuels, enhance energy security, prevent global warming, and better environmental quality. On a microeconomic level, for achieving energy efficiency’s the main objectives are cost minimisation, reduction of energy use when prices increase, and seeking substitutes or clean energy.

This analysis seeks to measure energy efficiency development from a production theoretic framework, and uses Data Envelopment Analysis (DEA) to present several alternatives models for measuring energy efficiency performance.

Three alternative models were used in this study. The first two models measure the potential reduction in energy use when maintaining output levels and without including additional amounts of other inputs (technical efficiency); a third model (cost efficiency) considers energy efficiency based on the objective of minimising total input costs (these models were developed by Mukherjee, 2008 in the US manufacturing sector).

The fourth model analyses the energy mix effects for energy efficiency and calculates Malmquist indices for the total factor of productivity (TFP), technological change (TC), and technical efficiency up to the output level (desirable output) and CO₂ emissions (undesirable output). It considers four categories of energy consumption by source as inputs, namely electricity, petroleum products, gas, and other energy. It also considers as undesirable output the reciprocal of CO₂ emissions (in million tons). The fourth measure of energy efficiency mentioned under the literature reviewed could have been estimated but for the non-
availability of data pertaining the CO\textsubscript{2} emissions. It is high time that in a fast developing country like India the data like CO\textsubscript{2} emission are not properly collected along with the production statistics.

The most common definition of energy efficiency is energy intensity, defined as the quantity of energy required per unit of output or activity.

Data Envelopment Analysis (DEA) allows for the measurement of relative efficiency for a group of decision-making units (DMU) that use resources (inputs) to produce products (outputs). This methodology involves the use of linear programming methods to build a non-parametric piecewise frontier over data, so as to be able to calculate efficiencies relative to this frontier. Furthermore, DEA allows for the identification and quantification of inefficient DMUs when it has several inputs and outputs. The definition of efficiency in DEA consists of three components: technical efficiency, which reflects the ability of a firm to obtain maximal output from a given set of inputs, allocative efficiency, which reflects the ability of a firm to use inputs in optimal proportions, given their respective prices, and scale efficiency, which, according to the features of performance scale, brings about the DMU. These three measures are then combined to provide a measure of total economic efficiency.

From an economic perspective, it is insufficient to simply achieve technical efficiency. To achieve cost efficiency, a firm needs also to be efficient in its allocation of inputs, given input prices. Over time, since prices of different inputs need not change at the same rate, a DMU would need to change input proportions in response to changes in relative prices in order to achieve minimum costs. Model (3) allows for the measurement of cost efficiency for a DMU.

Regarding cost minimising inputs, model (3) analysed input prices. The ratio of the optimal amount of energy (as obtained from the cost minimisation model) to the actual amount of energy used allows us to obtain a measure of energy efficiency based on cost minimisation. If the current input–output combination is allocatively inefficient, then cost minimisation would require changing input proportions, which implies input substitution.

The three measures of energy efficiency were similar, indicating that energy efficiency improvement is necessarily an appropriate combination of technical efficiency and cost minimisation. On the other hand, in the Colombian case (referring review of literature), we saw
that the highest energy efficiency measured was from the cost minimisation model, suggesting that the relative price of energy in Colombian manufacturing industry does not reflect the real cost of using energy. As such, energy is the relatively cheaper input. Therefore, it is worthwhile to note that, in some regions, especially over the last years, energy prices have brought about energy efficiency improvement, whereas, in different other regions of the world, energy prices have not generated the proper incentives to improve energy efficiency. Manufacturers and industry analysts say that the most important factor in determining whether or not to implement energy savings measures is price and cost of energy and this fact coincides with the results of the cost efficiency estimate of the present study as well.

Although cost efficiency varies across states, among this Karnataka had a disturbingly very low score. Kerala had a better score than Andhra Pradesh and Tamil Nadu. In fact, Andhra Pradesh and Tamil Nadu had a comparatively similar score as the differences being not much remarkable (referring Table 5.2.1). The presence of significant cost inefficiency implies that there is, indeed, a potential for Indian firms to become far more cost-competitive which could enable them to gain a larger share of the world market even within the capabilities defined by the current technology. There is reason for optimism on this count. At the same time, one must recognize that eliminating the existing inefficiencies would be a major challenge and a bright future for industries is far from assured.

With the econometric model developed (in the study) for the identification of determinants of energy efficiency and to study its simulated implications on energy efficiency based on the adjusted $R^2$, we could capture roughly 92 percent of the phenomenon of encouraging energy efficiency in the developing context of Kerala. In fact, the impact of the different determinants on the phenomenon of energy efficiency we got simulated by increasing them by 10%, 20% as well as by reducing them by 10%, 20% from their base run and the pattern got graphed. The simulated impacts of technical efficiency (which reflects the ability of the firm to produce maximum output from a given set of inputs including technology) has been found to be more explicit than that of the allocative efficiency (the ability of the firm to use inputs in optimal proportions, given their respective prices). Also, the simulations of the material used per output as well as the intensity of energy utilisation (that is, the energy utilised per output) are depicting
more or less similar patterns (the higher energy intensity being consistent with the extend of materials processed in the manufacturing process).

The present study highlights the importance of developing data on variables like CO$_2$ emissions in manufacturing. Knowledge development on problem like energy efficiency remains incomplete if the study sidelines the pollution aspects of energy utilisation.

**Notes and References**