Energy Efficiency in India's Iron and Steel Industry: A Firm-level Data Envelopment Analysis

Ramphul Ohlan

ABSTRACT

India's national mission to improve energy efficiency focuses on enhancing the efficiency in its most energy-intensive industries. Motivated by this mission, we measure and analyze energy efficiency in the country's iron and steel industries applying data envelopment analysis using firm-level panel data over the period 2004-2012. The results show that the energy efficiency of India's iron and steel industries has improved and energy intensity has declined during the study period. However, there is a large potential for these industries to further reduce energy use. The results of the regression analysis obtained using panel data indicate that larger firms tend to have higher energy efficiency. In addition, labor productivity improves energy use efficiency. Improvements in energy efficiency, particularly in small and medium firms should be encouraged.

INTRODUCTION

The International Energy Agency (IEA) states "energy efficiency needs to be central in energy policies around the world" [1]. Improvements in energy efficiency are emerging as key policy solutions for ensuring energy security, reducing energy costs and controlling environmental pollution. The efficient use of energy is also imperative for enhancing the competitiveness and strengthening the sustainability of energy-intensive industries [2]. The iron and steel manufacturing industries are highly energy-intensive and increase emissions. However, iron and steel are vital inputs that fuel economic growth. Energy production and transmission also rely heavily on steel. Efficient use of energy in iron and steel manufacturing is central to achieving the goal of sustainable economic growth.

The chief objective of the study was to measure energy efficiency in the Indian iron and steel industries, the county's largest industrial energy user. This sector accounted for 21% of India's total industrial energy consumption in 2013 and its share is projected to increase rapidly, reaching 29% in 2040 [3]. Furthermore, expenditures on power and fuel constitute key components of total manufacturing cost, ranging between 40% to 60% for a typical iron and steel company.

Due to the industry's rapid growth, India is the third largest producer of crude steel in the world after China and Japan; India is expected to overtake the Japan before 2020. The growth in India's iron and steel industries is mainly due to: a) India's comparatively low per capita steel use, 60 kg per capita compared to the world average of 216 kg per capita; and b) the increase in the use of steel resulting from expanded infrastructure requirements, including the construction roads and railways. To meet the growing domestic demand, the country plans to increase the production of steel to 300 million metric tons by 2025 from 90 million metric tons by 2016.

India has established targets for reductions in energy use in various energy-intensive industries. Morrow III et al. projected that use of energy-efficient technologies could yield considerable energy savings in India's iron and steel industries [4]. It is clear that estimating and analyzing energy efficiency in the rapidly growing Indian iron and steel industries is informative to formulate and implement stronger energy efficiency policies.

There is a dearth of empirical literature on the analysis of energy efficiency in India's iron and steel industries. Very few studies of inputs use overall energy efficiency as a key variable. For instance, Debnath and Sebastian used data envelopment analysis (DEA) to evaluate the overall technical efficiency in India's iron and steel manufacturing industry for the year 2007-08 [5]. Economies of scale were noted in both the iron and steel industries. Likewise, Dwivedi et al. assessed the technical efficiency of India's leading steel manufacturing firms employing data envelopment analysis over the period 2006-2010 [6]. A considerable variation was reported in the technical efficiency levels of firms. However, Dwivedi et al. did not accommodate energy as an input for measuring the efficiency in Indian iron and steel industry [6]. Moreover, both of these studies used a DEA model in which the objective function was to equally minimize all inputs to the greatest amount feasible to maintain a given level of output instead of a reduction in energy input only. Existing studies did not attempt to explain variations in energy efficiency in the iron and steel industry.

By addressing such gaps, this study advances the extant empirical literature on energy efficiency in India using the production function approach where both energy and non-energy inputs are accommodated. The objective is to bring the largest feasible decrease in the energy input for obtaining a given level of output. This study is the first to investigate the energy efficiency of India's iron and steel industry at the firm-level using a theoretical production framework that excessively focuses on energy use. Factors affecting energy efficiency are also considered.

The empirical analysis provides better insights for implementing and understanding energy efficiency policy in one of the world's largest emerging economies. The DEA model and multiple regression model used in the study and their sources of data are discussed. The empirical results are presented along with conclusions from the analysis and their policy implications.

METHODOLOGY

For measuring the energy efficiency in Indian iron and steel industry, this study parallels Martinez and Mukherjee by using the data envelopment analysis model (DEA). It considers feasible decreases in energy consumption without reductions in output while avoiding the use of extra quantities of other inputs [2,7]. The model is specified as:

$$\theta^* = \min \theta \tag{1}$$

subject to

$$\sum\nolimits^{n}_{i-1} K_i \lambda_i \leq K_o$$
$$\sum\nolimits^{n}_{i-1} L_i \lambda_i \leq L_o$$
$$\sum\nolimits^{n}_{i-1} M_i \lambda_i \leq M_o$$
$$\sum\nolimits^{n}_{i-1} E_i \lambda_i \leq \theta E_o$$
$$\sum\nolimits^{n}_{i-1} y_i \lambda_i \geq y_o$$

$$\lambda_i \geq 0, i = 1, 2, \ldots, n$$

where θ^* = energy efficiency index, K = capital, L = labor, M = raw material, E = energy consumption and y = output. If θ^* =1, the firm is energy efficient, which means that no decrease in energy use is feasible, if θ*θ 1, the firm is energy inefficient.

Regression Analysis for Explaining Energy Efficiency

The multiple regression model used to analyze the changes in energy efficiency is as follows:

$$\theta^* = f(S, S^2, LP, CL)$$

where S = size of firm, LP = labor productivity,
and CL = the capital-labor ratio.

Data Sources

The output is defined in terms of the gross value of production and the inputs used in the study are: labor, capital, energy and materials. The firm level data in nominal terms are obtained from the electronic PROWESS database provided by Centre for Indian Economy for the period 2004 to 2012.

RESULTS AND DISCUSSION

Table 1 (see page 34) presents the estimates of energy efficiency assessed in terms of energy intensity and indices of efficiency obtained using the input oriented DEA model for India's iron and steel firms during the period of study. The average energy intensity of India's iron and steel industry is 0.059 implying that to produce $1 (U.S) worth of output, this industry uses on average $0.059 worth of energy.

It is evident from the results presented in Table 1 that India's iron and steel industries are becoming less energy intensive. The energy intensity has been improved by 0.011 percentage points between 2004 and 2012, reduced at a compound rate of 1.40 per annum. This means that in order to produce $1 worth of iron and steel, expenditures on energy declined from $0.069 in 2002 to $0.058 in 2012. This finding indicates that reducing energy costs is a high priority in terms of improvements in production process. However, the observed pace of energy intensity improvement in the industry is moderate.

The results presented in row 3 of Table 1 show that the average energy efficiency index for Indian iron and steel industry is 0.871. This implies that it is feasible to decrease energy use by 12.9% while maintaining the same level of production without utilizing additional amounts of other inputs. The energy efficiency index indicates a statistically significant rising trend. The efficiency index registered a compound annual growth rate of 1.67% during the period of study. This finding corroborates the earlier finding regarding the iron and steel industry's priority of energy saving. The improvement in energy efficiency may be partially attributed to energy efficiency interventions instituted by the Government of India under the Energy Conservation Act (2001). However, there still exists a large potential for enhancing energy efficiency in India's iron and steel industry. This finding concurs with projections of energy saving potential provided by Morrow III et al. [3].

Explaining Energy Efficiency

The results of regression analysis performed to investigate the changes in energy efficiency using panel data are presented in Table 2, which indicates that firm size has a positive and statistically significant impact on energy efficiency. This finding concurs with the findings of Martinez who studied energy-intensive manufacturing industries in Germany and Colombia [2]. However, the negative estimate of influence of $size^2$ on energy efficiency reveals that an increase in firm size initially improves energy efficiency and then decreases after reaching an optimal size. In addition, labor productivity significantly enhances energy efficiency. This result corroborates the finding of Mukherjee in the context of India's manufacturing sector [7]. The coefficient of capital labor ratio is not statistically significant, implying that capital-intensive technology does not guarantee energy savings.

The results of diagnostic tests presented in the last three rows of Table 2 show that the estimates of parameters are robust and fit for reliable interpretation. Specifically, the calculated value of R^2 reveals that about 50% of total variation in the energy efficiency score is explained by the model used. The statistical significance of the estimated value of F-statistic indicates that the overall fitness of the regression analysis is good.

CONCLUDING REMARKS

The DEA model is applied to assess the energy efficiency of India's iron and steel industry using firm-level panel data for the period from 2004 to 2012. The results show that on an average, iron and steel firms

Table 1.
Results of energy efficiency in India's iron and steel industry.

Year	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*Average*	*CAGR*
E/Y	0.069	0.060	0.060	0.054	0.053	0.059	0.059	0.056	0.058	0.059	-1.40*
θ	0.852	0.787	0.883	0.811	0.864	0.879	0.902	0.893	0.964	0.871	1.67*

Notes: CAGR, compound annual growth rate. * significant at 1% level.

Table 2.
Estimates of fixed effect panel regression for analyzing energy efficiency.

Variable	*Estimated Coefficient*	*Std. Error*	*t-Statistics*	*Probability*
Intercept	0.8334*	0.0176	47.2278	0.0000
Size	1.26E-06*	2.41E-07	5.6708	0.0000
$Size^2$	-1.57E-12*	3.03E-13	-5.7072	0.0000
LP	0.0002*	0.0001	1.1968	0.0139
CL	6.30E-05	6.09E-05	1.0351	0.2322
R^2	0.5087			
F-statistic	7.6242*			0.0000
Durbin-Watson statistic	1.5774			

Notes: * indicates significance at 1% level. CL, capital labor ratio.

have witnessed an enrichment in energy efficiency and reduction in energy intensity during the period studied. It indicates that energy savings is a high priority for India's iron and steel industries. However, there is potential for further energy efficiency improvements. The results from the panel data regression analysis reveal that energy efficiency first improves as firm size increases, then declines after reaching a certain level of size. In addition, labor productivity is found to be positively and significantly associated with energy efficiency. The policy implication of our findings is clear. To achieve the goal of improved energy efficiency, particularly for small and medium-sized firms, encouragement is required.

Presently, most of India's iron and steel plants are coal-fired. The modernization and expansion of steel plants is desirable not only to improve energy efficiency but also for environmental sustainability. About 70% of the coking coal requirement of the industry is supplied by imports. Clearly, switching steel plants to natural gas-based coking has positive overseas environmental externalities. As has been emphasized by Government of India in its draft National Steel Policy 2017, there is an urgent need to promote natural gas-based steel plants, electric/induction furnaces and other technologies which will lower usage of coking coal in blast furnaces [8].

Improvements in energy efficiency in the iron and steel industries are essential to accomplishing India's nationally determined contribution goals. These include reducing the emissions intensity of the country's gross domestic product by 33% to 35% by 2030 compared to 2005 levels, as ratified in the Paris Agreement. The findings of this empirical analysis are also useful for other developing countries to establish a sustainable and competitive low-energy iron and steel industry.

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References

[1] International Energy Agency (2016). *Energy efficiency market report 2016*. World Energy Outlook Special Report. Paris: IEA.

[2] Martinez, C. (2015). Estimating and analyzing energy efficiency in German and Colombian manufacturing industries using DEA and data panel analysis. Part I:

Energy-intensive Sectors. *Energy Sources, Part B: Economics, Planning and Policy*, 10(3), pages 322–331.
[3] International Energy Agency (2015). *India energy outlook*. World Energy Outlook Special Report. Paris: IEA.
[4] Morrow III, W., Hasanbeigi, A., Sathaye, J. and Xu, T. (2014). Assessment of energy efficiency improvement and CO_2 emission reduction potentials in India's cement and iron and steel industries. *Journal of Cleaner Production*, 65, pages 131–141.
[5] Debnath, R. and Sebastian, V. (2014). Efficiency in the Indian iron and steel industry—an application of data envelopment analysis. *Journal of Advances in Management Research*, 11(1), pages 4–19.
[6] Dwivedi, A., Ghosh, P. and Dangayach, G. (2013). Efficiency measurement of Indian steel industry using data envelopment analysis. *International Journal of Operational Research*, 18(4), pages 386–400.
[7] Mukherjee, K. (2008). Energy use efficiency in the Indian manufacturing sector: an interstate analysis. *Energy Policy*, 36, pages 662–672.
[8] Government of India (2017). National steel policy. http://steel.gov.in/PDF/DRAFT%20NATIONAL%20STEEL%20POLICY%202017.pdf, accessed 14 April 2017.

ABOUT THE AUTHOR

Ramphul Ohlan teaches at Maharshi Dayanand University, Rohtak in Haryana, India. Professor Ohlan has published his theoretical and applied research work independently in international journals that include *Energy Sources, Part B: Economics, Planning, and Policy*; *Natural Hazards; Social Indicators Research*; *Future Business Journal*; *Agricultural Economics*; *South Asia Research*. His books include: *Generalizations of Fuzzy Information Measures*, Springer, and *Globalization and Dairy Industry*.