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Research paper

Energy Intensity analysis of Indian manufacturing industries

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ABSTRACT

Energy has been recognized as one of the key inputs for the economic growth and social development of a country. India being one of the largest and rapidly growing developing countries, there is an impending energy crisis which requires immediate measures to be adopted. In this situation the concept of Energy Intensity comes under special focus to ensure energy security in an environmentally sustainable way. Energy Intensity of Indian manufacturing industries is among the highest in the world and stands for enormous energy consumption. Hence, reducing the Energy Intensity of Indian manufacturing industries is one of the challenges. This study attempts to analyse the factors which influence the Energy Intensity of Indian manufacturing industries and how they can be improved to reduce the Energy Intensity. The paper considers five of the largest energy consuming manufacturing industrial sectors in India viz. Aluminium, Cement, Iron & Steel Industries, Textile Industries and Fertilizer Industries and conducts a detailed Energy Intensity analysis using the data from PROWESS database of the Centre for Monitoring Indian Economy (CMIE) for the period 2005–2014.

1. Introduction

Energy is the most fundamental and essential requirement for the survival and growth of all living things on earth. Energy has been recognized as one of the key inputs for the economic growth and social development of a country. It is well established that the relationship between economic growth and energy consumption is mutually dependent and serves as a clear indication of the quality of life. The global demand for energy has been ever increasing, fuelled by rapid industrialization, changes in the demographic structure, rising urbanization, technological progress and socio-economic development. The huge increase in the energy demand, the acute deficit in the energy generation and the depletion of conventional energy resources has been realized to be a very complex issue for which an easy solution does not exist. Energy intensity is a related concept and is an indicator which shows how efficiently energy is being utilized in an economy [1,2].

Energy intensity is defined as the energy consumed per unit output in the context of industrial energy practices. Also, it is a key determinant of the projections of future energy demands. Energy intensity is inversely related to energy efficiency; lesser is the energy required to produce a unit of output or service, the greater is the energy efficiency. India being one of the largest and rapidly growing developing countries, the issue of attaining the desired levels of energy efficiency with low levels of energy intensity needs special focus. Understanding the causes of underlying trends in energy intensity is both an essential step to energy conservation and a rough basis for projecting the requirements of energy consumption and the associated environmental effects [3,4]. However, precise information on the influence of factors like structural changes and economic changes on the energy intensity in India has not been studied thoroughly so far. This leaves a gap in India's energy literature regarding the dimensions of energy use and intensity. In this context, the current work examines the different factors affecting the energy intensity and the usefulness of such energy intensity indicators in reducing the energy intensity [5,6].

The major energy intensive manufacturing industries in India are that of iron and steel, chemical, textiles, aluminium, fertilizers, cement and paper, of which aluminium industry is the most energy intensive followed by iron and steel industry. These industries account for over 60% of the energy consumed within the industrial sector [7,8].

The purpose of this paper is to identify the explanatory factors having impact on energy intensity in different Indian manufacturing industries and to investigate the impact of these factors on Energy Intensity in the Cement, Iron & Steel, Textiles, Aluminium and Fertilizer Industries.

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2. Literature review

The following review gives a comprehensive idea about the kind of efforts which have been put in by various researchers to find out the energy intensity indicators their relative effects pertaining to manufacturing industries both at global level and national level. There have been attempts to measure and examine the degree of energy intensity of seven major manufacturing industries of India viz. Paper, Aluminium, Iron & Steel, Fertilizer, Chemical, Glass and Cement, at an industry level [9]. The energy input ratio is calculated as a relation of energy cost to the total input of manufacturing activities. The study observes whether there exists any inter-industry variation in energy intensity and depicts varied energy intensities which are well above the average intensity of the entire aggregate manufacturing industry. It also reveals that there are variations of energy intensity among different industries over time and with respect to economic activities [10].

Reddy and Ray in their study [11,12] aim to determine the physical Energy Intensity indicators in five industrial sub-sectors i.e. iron & steel, aluminium, textiles, paper & pulp and cement and investigate the options for carbon dioxide reduction (during 1991–2005). The use of physical energy intensity indicators improves comparability between countries, enables designing policies for improving productivity and reduce energy consumption in India's manufacturing sector. Decomposition analysis was employed to separate the structural effect (share of different products in the sector) from pure intensity effect (efficiency increase through technical improvement) for each industry. The results show that the combined effect (considering both structural and intensity effects together) on both iron & steel and paper & pulp industries is negative while it is positive for aluminium and textiles. In the case of aluminium, positive structural effect dominates over negative intensive effect whereas negative intensive effect dominates iron & steel industry [13,14].

Study of the determinants of total factor productivity (TFP) of Indian manufacturing industries is conducted [3] using transcendental logarithmic production function. Labor, capital, material and energy are the inputs considered for the estimation of TFP. The findings of the paper suggest that labor and material inputs play major role as compared to the capital and energy input. The finding of the estimates suggest that age of the firm, export intensity and disembodied technology import are positively related to the TFP, where ownership, energy intensity, embodied technology import and R&D intensity are negatively related to the TFP of the firms for Indian manufacturing. This implies the need for promotion of energy efficiency at firm level in Indian manufacturing.

3. Dependent and explanatory variables

For the proposed work, the dependent variable is taken as Energy Intensity (EI) which is often used as a measure of energy efficiency. It is defined as the ratio of the power and fuel expenses to net sales of the industry over a period of fixed time. In the technical concept, energy efficiency increases when either energy inputs are reduced for a given level of output or there are increased or enhanced output for a given amount of energy inputs. If energy efficiency increases, the dependent variables i.e. Energy Intensity is reduced.

The various explanatory variables having impact on the Energy Intensity in the selected industrial sectors are explained as follows.

1. Labor Intensity (LI) is defined as the ratio of the wages and salaries to the employees to the net sales of the industry. An industry that requires a large amount of labor to produce its goods or services will be more labor intensive.
2. Repair Intensity (RI) is defined as the ratio of total expenses on repairs of plant and machineries to net sales of the industry. More expenditure on repairs of plant and machineries implies that they have become inefficient and hence a high value of Repair Intensity will lead to a larger value of Energy Intensity (EI) i.e. the industry is more energy intensive. This means that Repair Intensity is expected to have a positive coefficient.
3. Technology Development Intensity (TDI) is defined as the ratio of total amount spend on technology development to the net sales of the industry. The total amount spend on technology development is the sum of domestic royalties, technical knowhow fees, Forex spending on royalty/ technical knowhow. In developing countries like India, technology development intensity is the most important source of knowledge acquisition by industry. The Technology Development Intensity (TDI) is likely to affect the Energy Intensity (EI).
4. Raw Materials Intensity (RMI) is defined as the ratio of expenditure on raw materials, and spares to the net sales of the industry. The Raw Material Intensity (RMI) is inversely related to Energy Intensity. More the money spent on raw material and spares better will be the Energy Intensity (EI).
5. Outsourcing Intensity (OI) is defined as the ratio of sum of outsourced professional jobs, outsourced manufacturing jobs and consultancy fees to others to net sales of the industry. More the expenses on outsourcing in the industry better will be the Energy Intensity (EI).
6. Software Intensity (SI) is defined as the ratio of sum of IT enabled services charges, software charges, and other professional services to net sales of the industry. Software Intensity is directly related to Energy Intensity (EI).
7. Plant and Machinery Intensity (PMI) is defined as the ratio of expenses on plant and machinery, computers and electrical assets to net sales of the industry. Better is the Plant and Machinery Intensity (PMI) better would be the energy efficiency.
8. Profit After Tax Intensity (PATI) is defined as the ratio of profit after tax to net sales of the industry. It is possible to increase the industry earnings while decreasing the profit, meaning that the industry is becoming relatively less efficient. The most obvious, easily identifiable and broad numbers that affect the profit intensity are net profits, sales earnings and merchandise costs.

4. Proposed model

The standard econometric approach is used to develop the model using the panel data available on Indian manufacturing industries of different sectors. Basically the Indian manufacturing industries are divided in five different sectors. Within each sector the data is collected at firm level. Multiple regression model technique is used to analyze the data. The proposed panel data model for analysis using the above discussed explanatory variables takes the following functional form.

$$\begin{aligned} EI = \alpha &+ (\beta_1 \times LI) + (\beta_2 \times RI) + (\beta_3 \times TDI) + (\beta_4 \times RMI) \\ &+ (\beta_5 \times OI) + (\beta_6 \times SI) + (\beta_7 \times PMI) + (\beta_8 \times PATI) + C_i \end{aligned}$$

where,
EI = Energy Intensity (Dependent Variable)
α = EI intercept
β_1 = Coefficient of LI
β_2 = Coefficient of RI
β_3 = Coefficient of TDI
β_4 = Coefficient of RMI
β_5 = Coefficient of OI
β_6 = Coefficient of SI
β_7 = Coefficient of PMI
β_8 = Coefficient of PATI

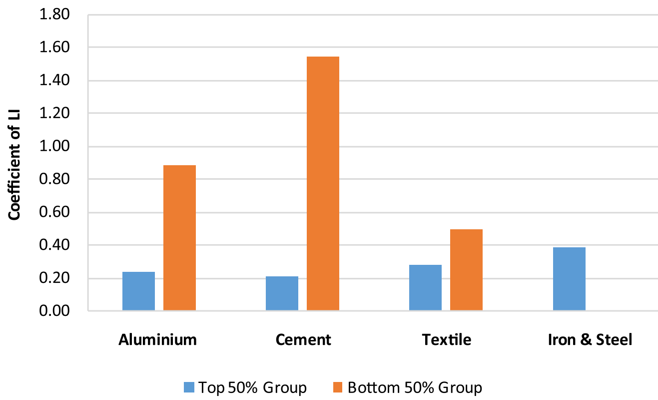

Fig. 1. Effect of Labor Intensity.

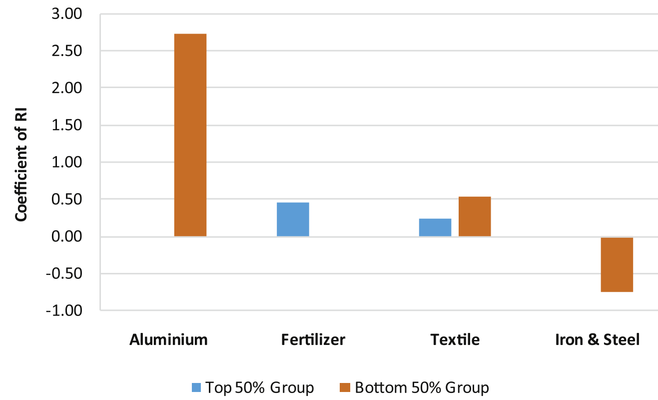

Fig. 2. Effect of Repair Intensity.

C_i = Individual specific effect (dummy used for the industry if it is highly energy intensive)

5. Methodology

The various sectors in the Indian manufacturing industries are identified on which the Energy Intensity analysis is to be carried out. A detailed study of explanatory variables is to be carried out to interpret their impact on the Energy Intensity for the selected Indian manufacturing sector.

A study is conducted on the available econometric models and their relative features are analysed to propose a suitable model for the system. A statement of theory or hypothesis is then formulated to specify the expected correlation between the dependent variable (Energy Intensity) and the various explanatory variables.

Data samples for various industries under five different Indian manufacturing sectors i.e. Cement, Iron & Steel, Textiles, Aluminium and Fertilizer Industries, are collected from the Centre for Monitoring Indian Economy (CMIE) for a duration of ten years i.e. from April 2005 to March 2014.

Sorting of the collected data is done by the increasing order of Energy Intensity taking 2014 as the base year and then the data is refined and filtered for each of the individual sectors.

Then the industries of each sector are arranged in two groups based on their Energy Intensity, with one group of industries having lesser values of energy intensity (top 50%) and another group of industries having greater values of energy intensity (bottom 50%).

For the different explanatory variables, calculation is done based on the arranged data for finding out the relationship between the Energy Intensity and the explanatory variables. A software (SPSS Version 17) is employed to carry out the calculations based on linear regression by stepwise method or multiple regression.

6. Result and analysis

The impact of each explanatory variable on the dependent variable Energy Intensity (EI) of the different sectors and for their sub groups (top 50% and bottom 50% groups) have been discussed below based on the multiple regression carried out for different industrial sectors for top 50% and bottom 50% as discussed above.

The impact of Labor Intensity (LI) on the Energy Intensity for Aluminium, Cement, Textile and Iron & Steel sectors have been shown in Fig. 1 For the Fertilizer sector, LI has been excluded after regression since found to be insignificant. It can be seen that coefficient of LI is positive for all the sectors and all the sub groups. It is more significant for the bottom 50% group of each sector which means to reduce Energy Intensity, the amount of expenses on labor must be optimized, as per the hypothesis above.

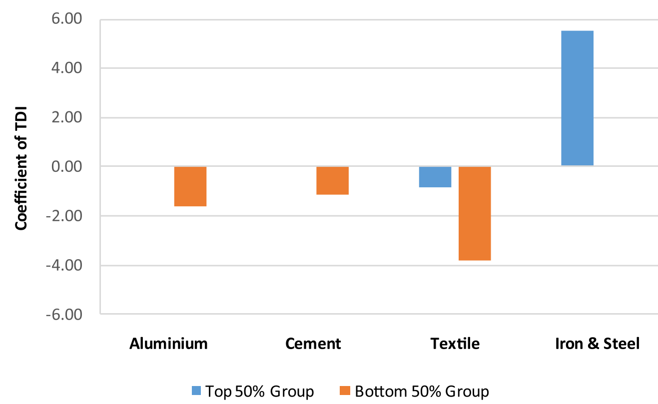

Fig. 3. Effect of Technology Development Intensity.

The impact of Repair Intensity (RI) on the Energy Intensity for Aluminium, Fertilizer, Textile and Iron & Steel sectors have been shown in Fig. 2. For the Cement sector, RI has been excluded after regression since found to be insignificant. It is observed that coefficient of RI is positive for Aluminium, Fertilizer and Textile sectors and it is negative for Iron & Steel sector as a typical case. It is most significant for the bottom 50% group of Aluminium sector which indicates that these groups of industries need to reduce their expenses on repair to reduce Energy Intensity. The hypothesis is validated for Aluminium, Fertilizer and Textile sectors.

The impact of Technology Development Intensity (TDI) on the Energy Intensity for Aluminium, Cement, Textile and Iron & Steel sectors have been shown in Fig. 3. Only for the Fertilizer sector, TDI has been excluded after regression since found to be insignificant. It can be observed that coefficient of TDI is positive only for top 50% group of Iron & Steel sector whereas for all sectors it is negative.

The impact of Raw Materials Intensity (RMI) on the Energy Intensity for Aluminium, Cement, Fertilizer, Textile and Iron & Steel sectors have been shown in Fig. 4. It can be concluded that coefficient of RMI is negative for all the sectors and majority of the sub groups as expected from the hypothesis. It is more significant for both the sub groups of Cement sector and in general, more significant for the bottom 50% group of all sectors. This clearly indicates the industries in the bottom 50% group must concentrate on RMI in order to reduce Energy Intensity in accordance with the hypothesis.

The impact of Outsourcing Intensity (OI) on the Energy Intensity for Fertilizer, Textile and Iron & Steel sectors have been shown in Fig. 5. For the Aluminium, Cement and Paper sectors, OI has

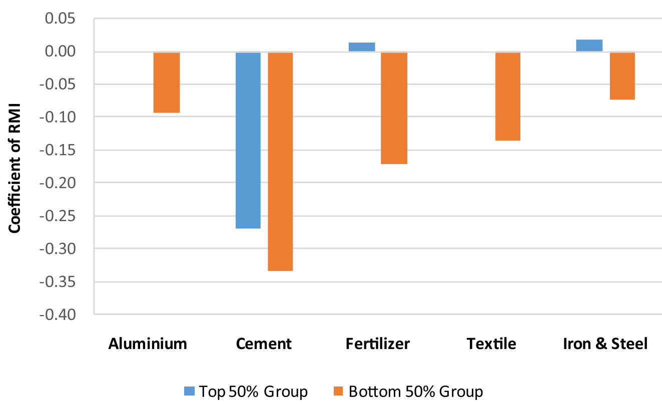

Fig. 4. Effect of Raw Materials Intensity.

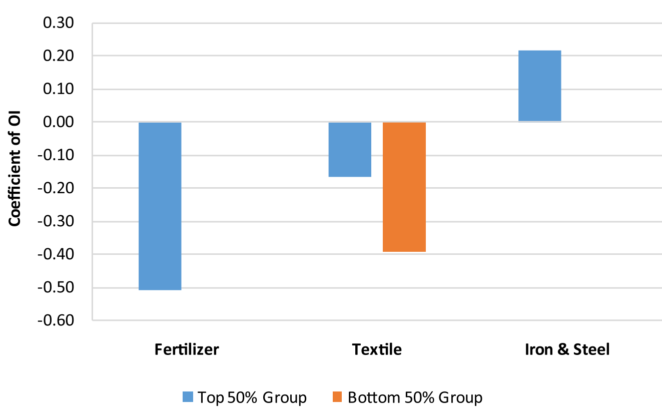

Fig. 5. Effect of Outsourcing Intensity.

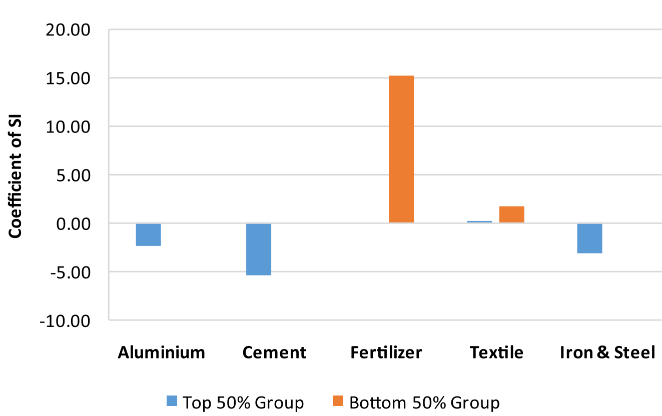

Fig. 6. Effect of Software Intensity.

been excluded after regression since found to be insignificant. It is observed that a negative relationship exists between OI and EI for Fertilizer and Textile sectors, although Iron & Steel sector shows a positive relationship. For the top 50% group of Fertilizer sector, the OI is most significant. Thus the hypothesis is validated for Iron and Steel sector only.

The impact of Software Intensity (SI) on the Energy Intensity for all sectors have been shown in Fig. 6. SI is having a positive relationship with EI in Fertilizer, Paper and Textile sectors whereas it shows a negative relationship for Aluminium, Cement and Iron & Steel sector. It is most significant for the bottom 50% group of Fertilizer sector and least significant for bottom 50% of Paper sector. It is inferred that Investment in software based production system may not have substantial effect on energy intensity reduction.

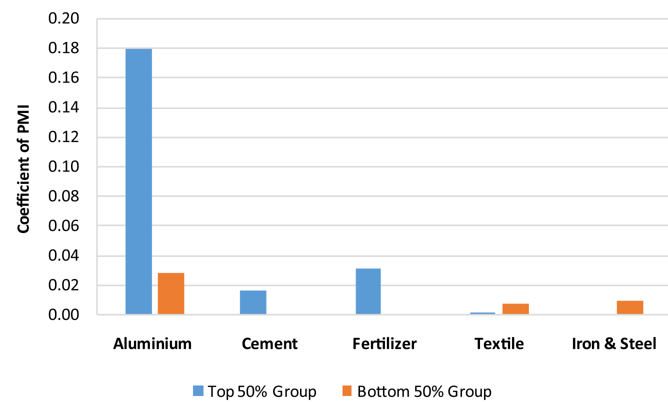

Fig. 7. Effect of Plant & Machinery Intensity.

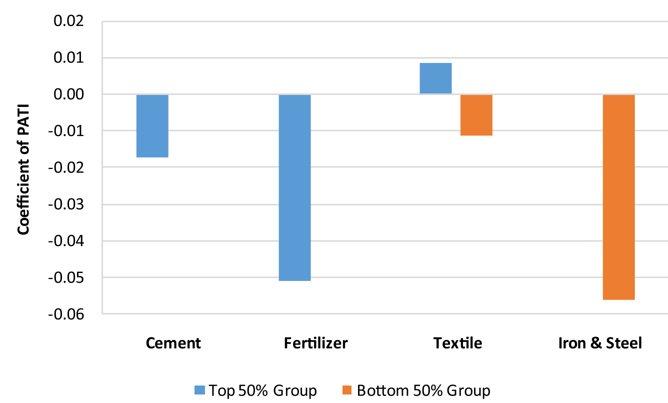

Fig. 8. Effect of Profit After Tax.

The impact of Plant and Machinery Intensity (PMI) on the Energy Intensity for Aluminium, Cement, Fertilizer, Textile and Iron & Steel sectors have been shown in Fig. 7. It is observed that coefficient of PMI is positive for all the sectors and sub groups. It is most significant for the top 50% group of Aluminium sector which indicates that this group of industries may be spending a high amount on plant and machinery which is not contributing directly to energy efficiency. Thus this group needs to carefully examine the expenses on plant and machinery and invest wisely in the technology which contributes in reducing the Energy Intensity. This is as per the hypothesis, “Better is the Plant and Machinery Intensity (PMI) better would be the energy efficiency.”

The impact of Profit After Tax Intensity (PATI) on the Energy Intensity for Cement, Fertilizer, Paper, Textile and Iron & Steel sectors have been shown in Fig. 8. For the Aluminium sector, PATI has been excluded after regression since found to be insignificant. It is observed that for most of the sectors PATI is found to have a negative relationship with EI in line with the hypothesis. It is more significant for the top 50% group of Fertilizer sector and bottom 50% group of Iron & Steel sector.

7. Conclusion

The Energy Intensity (EI) analysis was carried out using stepwise linear regression for all the five sectors of Indian manufacturing industries. Each sector was further subdivided into two groups based on Energy Intensity (EI) to establish a better correlation between the variables. This work is an attempt to understand the factors determining the influence of various parameters on Energy Intensity in Indian manufacturing industries using data from the Prowess database of CMIE for the period April 2005 to March 2014.

An important observation was made in the case of Labor Intensity (LI) where it was found to have a positive relationship with all the sectors and sub groups. The impact of PMI was found to be most significant in the top 50% group of Aluminium sector which indicates that this group of industries need to reduce their expenses on plant and machinery to reduce their Energy Intensity. For most of the sectors PATI was found to have a negative relationship with EI, particularly more significant for the top 50% group of Fertilizer sector and bottom 50% group of Iron & Steel sector.

The study has confirmed that analysis of Energy Intensity plays a vital role in understanding the energy use patterns of the Indian manufacturing industries. It can be concluded that reduction in Energy Intensity can be achieved by concentrating on its influencing factors, represented by the explanatory variables, and adopting appropriate measures to optimize them.

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