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Determinants of Energy Intensity in Indian Manufacturing Industries: A Firm Level Analysis

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Abstract

The demand for energy; particularly for commercial purposes, has been growing rapidly with growth of the economy, changes in the demographic structure, rising urbanization, socio-economic development, and the desire for attaining and sustaining self-reliance in some sectors of the economy. Energy intensity of Indian industries is among the highest in the world and specifically the Indian manufacturing sector is the largest consumer of energy sources. This study attempts to analyze the determinants of energy intensity of Indian manufacturing firms using data from the PROWESS database of the Center for Monitoring Indian Economy (CMIE) for the period 2000-2008. The results of the econometric analysis suggest a non-linear (U shape) relationship between energy intensity and firm size, implying that both very large and very small firms tend to be more energy intensive as compared to the medium size firms. The analysis also highlights that, foreign owned firms are less energy intensive as compared to the domestic firms. Further, technology imports are found to be important in contributing to the decline firm-level energy intensity. The paper also identifies that there is a sizable difference in energy intensity between energy intensive firms and others. In addition, the result also shows that younger firms are more energy efficient as compared to the older firms.

Keywords: *Energy Intensity, Commercial Energy Consumption, Indian Manufacturing Industries, Determinants of Energy Intensity*

JEL Code Classification: *Q4, B23*

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1. Introduction

Energy has been universally recognized as one of the most important inputs for economic growth and human development. Earlier studies have found a strong two-way relationship between economic development and energy consumption (Dhungel, 2008). One of the most significant energy-related changes in last 20 years has been significant reduction in energy intensity in the world's developed countries. Between 1980 and 2001, the OECD's[1] energy intensity declined 26%; the Group of Seven's (G-7[2]) fell 29%; and the U.S. dropped 34% (IEA, 2007). However, energy consumption in developing countries increased more than fourfold over the past three decades and is expected to increase rapidly (IEA, 2007). Number of factors influence energy requirement of an economy, where economic growth is one of the most important factors. Economic growth is often accompanied by industrialization, electrification, and rapid growth of infrastructure. Economic growth tends to be directly correlated with increased energy consumption, at least to a certain point. Beyond a certain point however, further economic development actually can lead to structural shifts in the economy that reduce the prominence of energy consumption of an economy as higher income levels can lead to the development and diffusion of more technologically sophisticated and less energy intensive machines.

There has been a rapid rise in the demand of energy resources and consequently emission of greenhouse gas (GHG) due to structural changes in the Indian economy in the past fifty years. The energy mix in India has shifted towards coal, due to higher endowment of coal relative to oil and gas, which has led to a rapidly rising trend of energy emissions intensities (IEA, 2007). The energy intensity of India is over twice that of the matured economies, which are represented by the OECD member countries (IEA, 2007). However, since 1999, India's energy intensity has been decreasing and is expected to decrease (Planning Commission, Govt. of India, 2001). The decline in energy intensity in the Indian economy could be attributed to several factors; some of them being demographic shifts from rural to urban areas, structural economic changes towards less energy intensive industries, impressive growth of services, improvement in efficiency of energy use, and inter-fuel substitution.

Studies have been conducted in total factor productivity (TFP) and technical efficiency in Indian manufacturing industries (see: Mitra et al. 1998; Goldar, 2004). Studies have also focused on TFP of energy intensive industries in Indian manufacturing industries (see: Mongia and Sathaye, 1998). Many other studies have also been conducted to study determinants of R&D intensity in Indian Manufacturing at aggregate and disaggregate levels (see: Narayanan and Banerjee,

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[1] Organization of Economic Co-operation and Development

[2] This group known as the G-7 includes Japan, West Germany, France, Britain, Italy, Canada and the United States, organized in 1986

2006; Kumar and Saqib, 1996; Siddharthan and Agarwal, 1992 and Kumar, 1987). The analysis of demand for energy in Indian manufacturing industries, are also of much research interest in Indian context (see: Bhaduri and Chaturvedi, 2000). However, very few research efforts have been devoted to examine the determinants of energy intensity in Indian manufacturing. In addressing this issue, this study is an investigation of finding out the determinants of energy intensity of Indian manufacturing industries. The organization of this study is as follows. Section 2 of the study attempts to look at the existing review on the industrial energy consumption. Section 3 deals with the variables construction and the model specification. Section 4 is based on the data sources and descriptive statistics. The empirical result is discussed in section 5 and section 6 of the study concludes the paper.

2. Review of Literature

In energy economics literature, there are wide range of studies those deal with establishing the relationship between energy consumption and economic growth, the demand for energy in households, demand for energy in industries, and establishing the relationship between energy consumption and climate change. For example, Nguyen-Van (2008) has tried to find out the relationship between energy consumption and economic growth using semi-parametric panel data analysis. The findings suggest that energy consumption in developing countries would rise more rapidly than expected. Further, the result suggests that there will be serious challenges to economic and environmental problems in developing countries such as; rapid augmentation of greenhouse gas emission due to energy use, excessive pressure on the provision of energy resources, etc. The finding does not confirm the Environmental Kuznets Curve (EKC[3]) hypothesis. In addition, the study also depicts rapid increase in fossil fuel use in developing countries; also represent a growing contribution to the increase in local and regional air pollution as well as atmospheric concentrations of greenhouse gases such as carbon dioxide (CO2).

Studies dealing on energy demand in production sectors can be divided in two broad categories. The first category focuses on the demand for various types of

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[3]A Kuznets curve is the graphical representation of Simon Kuznets' hypothesis that economic inequality increases over time while a country is developing, and then after a certain average income is attained, inequality begins to decrease. A well-known hypothesis providing support for a policy that emphasizes economic growth at the expense of environmental protection is the Environmental Kuznets Curve (EKC) hypothesis. It posits that countries in the development process will see their levels of environmental degradation increase until some income threshold is met and then afterwards decrease. If true, economic policies should allow extensive, although not necessarily absolute, use of the environment for growth purposes. If developing countries decide to overlook environmental protection by counting on rising incomes to abate environmental damage the consequences could be devastating. The most pressing danger is that additional environmental degradation could cause some irreversible and significant harm. This could occur before the predicted income threshold is met. The other concern with counting on incomes to reduce environmental damage is that the EKC hypothesis could easily be incorrect and relying on its predictions would lead to consistently insufficient protection.

energy, which yields information about substitution possibilities between energy inputs say electricity and coal. The examples are Halvorsen (1977), and Pindyck (1979). The second category focuses on substitution possibilities between energy and other factors like labour, capital, and materials. The examples include Griffin and Gregory (1977) and Berndt and Wood (1975). In both the categories the models are typically estimated by a system of factor demand equations derived from cost minimization of firms using translog cost function. Using generalized Leontief functional form, Andersen et al. (1998) obtained price elasticity at -0.26 for the manufacturing sectors energy demand and the aggregate elasticity for various industrial sub-sectors ranging between -0.10 and -0.35.

Woodland (1993) used cross-section data for about 10,000 companies from 1977-85 for Australian state of New South Wales. This study uses a translog system with coal, gas, electricity, oil, labour, and capital included as factors of production. Woodland (1993) observes that only a minor share of the companies have a typical energy pattern where companies use all four types of energy. Woodland estimates a separate translog function for each observed energy pattern assuming that these patterns are exogenous due to technological constraints. Kleijweg et al. (1989) used panel of Dutch firms from 1978-1986 using translog functional form in estimating the aggregate energy demand. The long-run price elasticity of energy for the whole manufacturing sector in their study is found to be -0.56, while the long-run output elasticity is obtained at 0.61. Kleijweg et al. (1989) subsequently analyzed subsets of data divided by firm size, energy intensity, and investment level. They found that own price elasticity of energy increases with firm size and level of investments.

In an attempt to find out the demand for energy in Swedish manufacturing industries; Dargay et al. (1983) employed a translog cost function for 12 manufacturing sub-sectors from 1952-1976. The major variables used in the study include energy consumption, capital, labour and intermediate goods. The results indicate that relative changes in energy prices have significant effects on energy consumption. In conclusion, the findings suggest that rising energy prices can to some extent, be absorbed by substitution away from energy. The study concluded that the predominance of energy-capital complementarily is possible however; this adjustment may be accompanied by a deceleration in investment.

Similarly, Greening et al. (1998), tried to compare six decomposition methods and applied to aggregate energy intensity for manufacturing in 10 OECD countries, including Denmark, Finland, France, Germany, Japan, Italy, Norway, Sweden, United Kingdom and the United States from 1970 to 1992. The variables used in their study are total energy consumption, energy consumption by different sectors, total industrial production, production of different sectors, production share per sector, energy output ratio, and energy intensity. The energy intensity changes in the study indicate that the potential role of the cost of energy and cost of other factors of production are related to the changing pattern of aggregate energy intensity.

In order to examine the sectoral disaggregation, structural effect, and industrial energy use to analyze the interrelationships, Ang (1995) studied the manufacturing industries in Singapore from 1974 to 1989. He employed index decomposition based on changes in industrial energy consumption considering changes in aggregate energy intensity. Variables used in his study include energy consumption, total output, and energy intensity. His findings suggest that the impact of structural change can be large in energy demand projection based on simple extrapolation of historical sectoral production.

Mongia et al. (2001) reviewed the policy reforms and the productivity change in energy intensive industries in India. Using four inputs (KLEM[4]) model they have employed decomposition analysis of output growth and the residual representing the total factor productivity. They found that the overall productivity growth of energy intensive industries have gone down from 1973-1994; however, there is a significant difference in productivity growth across industries. Finding of this study implies that role of energy is an important input for output especially for the Indian energy intensive sector. The Berkeley lab on the energy studies have also analyzed the change in the total factor productivity in Indian manufacturing and found similar results for the select energy intensive industries.

Tyteca (1996) had given an extensive review of literature on the environmental performances of the firms in terms of externalities (as desirable and undesirable outputs). In this study, the author has considered the productive efficiency, where three factors of production are considered. Further, the study has argued that the previous econometric modeling or data envelopment analysis (DEA) analysis have not been able to address the issue of externality properly. However, he has tried to work with both parametric and non-parametric approaches of DEA analysis and concludes that energy pricing is one of the major indicators in determining performance of the firm. Hence, from the policy makers and researchers point of view, there is a need to understand the parameters of energy efficiency of firms.

There are very few studies those focus on the energy intensity analysis at the firm level. In this context, study by Vanden and Quan (2002) for China is relevant. They employed approximately 2,500 large and medium-sized industrial enterprises in China from 1997-1999 to identify the factors driving the fall in total energy use and energy intensity. Using an econometric approach, that identifies sources of variation in energy intensity they found that changing energy prices and research and development expenditures are significant drivers of declining energy intensity whereas changes in ownership, region, and industry composition are less important. In addition, the impact of R&D spending on energy intensity suggested that firms are using resources for energy saving innovations for the Chinese enterprises.

[4] In productivity analysis KLEM model defines output as a function of capital, labour, energy and material.

In an earlier attempt Sahu and Narayanan (2011) studied the determinants of energy intensity of Indian manufacturing for cross sectional data of 2007. Using an econometric approach the study identified variation in energy intensity. The result of the study found an inverted U shape relationship between energy intensity and firm size. The analysis also brings out the conclusion that ownership type is also an important determinant of energy intensity and foreign owned firms exhibit higher level of technical efficiency and hence less energy intensive. Further, the results of the study reveal that R&D activities are important contributors in reducing firm-level energy intensity. The study also identified that there is a sizable difference in energy intensity between higher energy intensive and less energy intensive firms. Based on the review of literature the objective of this work is to determine factors affecting the energy intensity of Indian manufacturing industries. The next section of the study deals with the methodology adopted, data sources and hypothesis of the study.

3. Variables Construction and the Model

Increase in energy efficiency might take place either when energy inputs are reduced for given consumption level, or there are increased or enhanced services for a given amount of energy inputs. In developing countries like India, import of technology is one of the most important sources of knowledge acquisition by any firm/enterprise. The technology imports are likely to affect energy intensity of firms. Technology imports include payment of technical fee, lump-sum payments for technology imports, payment of royalty to the foreign collaborator firms for using their trademarks and brand name. Whether, these innovation activities lead to product or process innovation, they might have measurable effect on energy intensity. Firms having long span of years in production (older firms) would likely to incur relatively more expenditure on R&D as compared to younger firms and hence, age of the firm may affect the energy intensity of such firms. Different types of industries use different types of technologies and the production structure differs hence, that exhibit different levels of energy intensity. To capture the intra-industry changes in energy intensity a dummy variable is created by classifying the sample into two categories based on the energy intensity as the higher and less energy intensive ones. If the value of energy intensity is greater than mean energy intensity it is considered as the energy intensive firms or else least energy intensive ones. The estimation is carried out following standard regression technique. The study uses the following list of variables (as given in Table 1) in the regression model. The regression equation takes the following functional form:

$$\begin{aligned}(energy\,\mathrm{int}) = \alpha + \beta_1 capital\,\mathrm{int} + \beta_2 labour\,\mathrm{int} + \beta_3 repair\,\mathrm{int} + \beta_4 rd\,\mathrm{int} + \\ \beta_5 tech\,\mathrm{int} + \beta_6 profit\,\mathrm{int} + \beta_7 size + \beta_8 size^2 + \beta_9 age + \beta_{10} age^2 + \\ \beta_{11} industrydummy + \beta_{12}\, firmdummy + u_i \qquad (1)\end{aligned}$$

Where: energyint: energy intensity, capitalint: capital intensity, labourint: labour intensity, repairint: repair intensity, rdint: research intensity, techint: technology import intensity, profitint: profit margin, size: size of the firm, size2: square of the size of the firm, age: age of the firm, age2: square of the age of the firm, industrydummy: dummy used for the firm if it's foreign owned, firmdummy: dummy used for the firm if considered as highly energy intensive

Table 1: Definition of variables used in the study

Sl.No	Symbol	Variable	Definition	Expected Sign
1	EI	Energy Intensity	Ratio of the power and fuel expenses to net sales	
2	LI	Labour Intensity	Ratio of the wages and salaries to the net sales	+
3	CI	Capital Intensity	Ratio of the total capital employed to net sales	+
4	TECH	Technology Import intensity	Ratio of the sum (of the forex spending on the capital goods, raw materials and the forex spending on royalties, technical know how paid by the firm to foreign collaborations) to net sales.	-
5	RDI	Research Intensity	Ratio of R&D expenses to net sales.	+ / -
6	PM	Profit Margin	Ratio of profit before tax to net sales	+ / -
7	RI	Repair intensity	Ratio of total expenses on repairs of plant and machineries to net sales	+
8	SIZE	Size	Natural log of total energy consumed in volume	-
9	AGE	Age	Subtraction of year of incorporation of firm from year of the study	+
10	FD	Firm Dummy	Dummy takes the value 0, if the firm is highly energy intensive and one for the rest	+
11	ID	Industry Dummy	Dummy takes the value one for the foreign owned firms and zero for the rest	-

Based on the literature and following Sahu and Narayanan (2011) this study proposes the following hypotheses to be tested: (1) capital intensive firms are energy intensive, (2) repair intensive firms are energy intensive and (3) foreign firms are energy efficient as compared to domestic firms.

4. Data sources and descriptive analysis

Energy intensity is often considered as a measure of energy efficiency. Energy intensity, typically constructed as the ratio of energy input to output, energy intensity provides a single, simple, easy to compute, summary measure of the efficiency with which energy is utilized (see: Freeman et al., 1997). Trends in energy intensity may not reflect the trends in technical efficiencies, but may reflect as changes in the structure of industry. Decrease in energy intensity may reflect that producers on an average are becoming efficient at producing the finished good.

Energy intensity in Indian industries is among the highest in the world. The manufacturing sector in India is the largest consumer of commercial energy[5]. In

[5] Commercial energy is energy used by commercial entities, as opposed to residential, industrial, or transportation energy

producing about a fifth of India's GDP, this sector consumes about 50% of the commercial energy. For example, energy consumption per unit of production in the manufacturing of steel, aluminum, cement, paper, textile, etc. is much higher in India, as compared to other developing countries (Planning Commission, Govt. of India, 2007). Mongia & Sathaye (1998) have classified Indian manufacturing industries based on energy intensity. According to their classification, the major energy intensive industries includes aluminium, cement, fertilizer, glass, iron & steel, and pulp & paper Industries.

The present study analyzes the determinants of energy intensity of Indian manufacturing sector, which is an improvement, to the earlier study by Sahu and Narayanan (2011). The improvements are based on the improvements in the definitions & construction of the variables and use of panel data for Indian manufacturing. In analyzing the determinants of the energy intensity we have used the standard multiple regression technique for panel data of nine years. The data for the analysis has been drawn from the online PROWESS database (as on September 2009) drawn from the Center for Monitoring Indian Economy (CMIE). The potential data set encompasses a large unbalanced panel consisting of 33,448 observations. Of these many are missing, which leaves 28,120 observations for the final analysis.

Before attempting the econometric model let us observe the relationship between the output and energy consumption pattern of Indian manufacturing from 2000-2008. Figure 1 presents the annual growth rates in energy consumption and output. It can be observed that the change in output and energy are fluctuating from 2000 to 2008. However, the change in growth rates of output is more volatile than that of the growth rate of energy consumption. The negative growth in output and energy consumption are not following similar pattern. In case of 2004, the negative growth in output is noticed; however the negative growth is not that sharp for energy consumption for the same year. When the energy intensity is drawn in the same figure, we can observe that the changes in energy intensity of the Indian manufacturing are also following the similar direction but the growth rates are much lower than the growth rate of output and energy consumption. As discussed by many researchers in energy economics literature, particularly addressing the issue of demand for energy in industries, the energy intensity changes accounts the effectiveness of the use of the energy per unit of output. Therefore, from the Figure 1, it is clear that energy consumption in Indian manufacturing industries is increasing however; per unit energy required for output is decreasing.

Most of the decomposition techniques (see: Ang, 1995) have found that energy intensity changes are due to either the sectoral changes in energy intensity or due to the change in the structure of the economy. However, this phenomenon has not widely tested for firm level or industry level analysis. To account for this relationship at firm level we have tried to observe the changes in output, energy consumption & energy intensity of the Indian manufacturing by plotting them (different scales are used for different variables on different axis where the X axis represents the year and Y and Z axis are based on different scales as per the value of the variables).

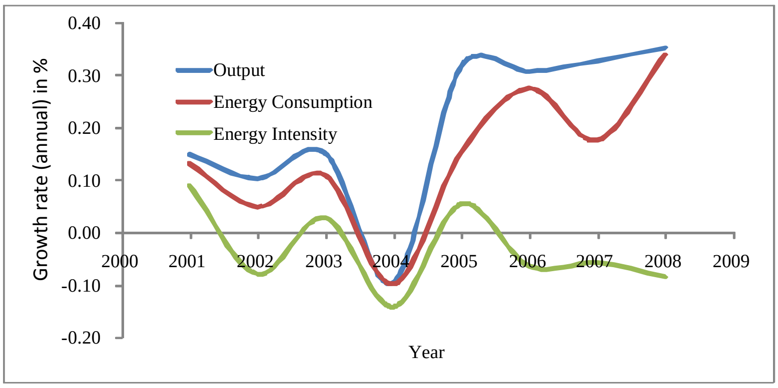

Figure 1: Annual growth rates of output, energy consumption & energy intensity in Indian manufacturing from 2000-2008

Figures 2 and 3, present the behavior of the three variables from 2000-2008. We can observe that output and energy consumption, are following same direction. When output increases, the energy consumption of Indian manufacturing also increases. Nevertheless, energy intensity follows differently as compared to output and energy consumption. From both the figures it can be noticed that, the energy intensity of Indian manufacturing is declining over the period whereas output and energy consumption are increasing. Hence, the energy use efficiency of Indian manufacturing is improving.

From the above discussion, it can be hypothesized that energy intensity is better explanation of firm's output as compared to energy consumption. There are many factors those influence energy intensity of the firms. However, based on the previous work on the cross-sectional study (Sahu and Narayanan, 2011) we have selected the most important variables those might influence energy intensity at firm level in Indian manufacturing.

Initial analysis of this study is carried out with the aggregate data, later on firm level analysis is being carried out. The energy intensity of Indian manufacturing industries at aggregate level suggests that non-metallic mineral products industries are the most energy intensive (13.24%) Industries followed by the textile industries. The machinery industries are found to be the least energy intensive. The aggregate data of Indian manufacturing industries show that miscellaneous manufacturing are the most labor intensive, which includes; paper & paper products, lather products etc. Chemical industries have resulted to be the least labor intensive ones. The textile industries are found to be capital intensive, where as the machinery industries are the least capital intensive. Research and development intensity of transport equipment industries are found to be highest as compared to other industries. However, the research intensity of the non-metallic mineral industries turned out to be the least.

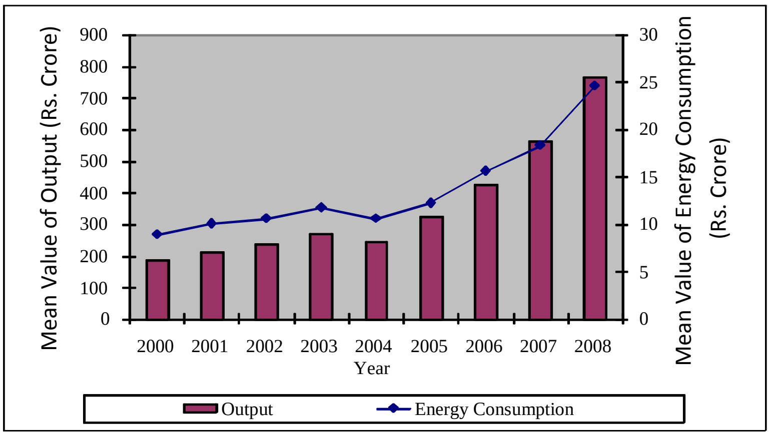

Figure 2: Mean changes in output, and energy consumption of Indian manufacturing from 2000-2008

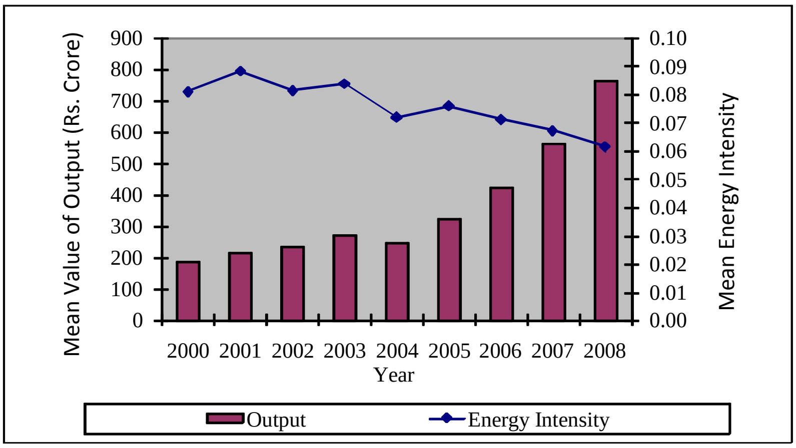

Figure 3: Mean changes in output, and energy Intensity of Indian manufacturing from 2000-2008

Metals and metal product industries are profitable as compared to other industries. The Machinery industry is characterized by least energy intensive as well as least labor intensive. However, the transport equipment industries are the capital intensive. The diversified manufacturing industries are categorized by least capital intensive, least technology import intensive as well as least export intensive.

The metal and metal product industries are found to be more labor intensive as well as least profit makers.

The above discussion attempted to find out the major key ratios (such as labor and capital intensity etc.) of Indian manufacturing sector at aggregate level and relate them with the energy intensity variation. The next section deals with the classification of the industries based on energy intensity. The values in the parenthesis in Table 2 are the value of energy intensities, based on three major classifications (this classification is defined based on percentile distribution of energy intensity divided in three categories as small, medium, and large). Based on the energy intensity classification, other variables are computed and presented in Table 2.

Table 2: Classification of industries as per energy intensity and variable characteristics

Indicators	Energy Intensity		
	Small	Medium	Large
Size	6.45	5.47	1.42
Capital Intensity	5.17	5.40	7.19
Labour Intensity	4.33	15.17	42.17
R&D intensity	6.35	3.96	3.43
Tech Import intensity	5.87	6.65	9.03
Repair Intensity	5.08	8.58	13.12
Profit intensity	6.87	5.44	5.83
Age	5.40	6.58	5.67

Source: Own estimates from PROWESS database, CMIE

From Table 2, it can be observed that smaller firms are energy intensive ones and capital intensive firms are energy intensive. The labor intensive firms are also energy intensive. Research and development expenditure might reduce the energy intensity of firms. The sample of 28,120 firms shows that research-intensive firms are energy efficient as compared to the least research-intensive firms. However, technology import intensive firms are energy intensive and vice versa. The preliminary result shows that repair intensive firms are also energy intensive ones. Profit of the firms may not be directly related to energy intensity of the firms; however, we suppose that they are indirectly related to the energy intensity. The preliminary findings suggest that profitable firms are energy efficient. It has been assumed that age of the firm has impact on energy intensity, mostly due to the hypothesis of learning by doing. The preliminary finding suggests that the medium aged firms are more energy intensive and older firms are less energy intensive ones.

Let us now look at the changes in energy intensity of the Indian manufacturing from 2000-2008. Figure 4 describes the changing patterns of energy intensity of Indian manufacturing. The energy intensity of the sample firms of Indian manufacturing industries are found to be highest in 2001 which declined in 2008. Energy intensity of Indian manufacturing is decreasing from 2000 to 2008.

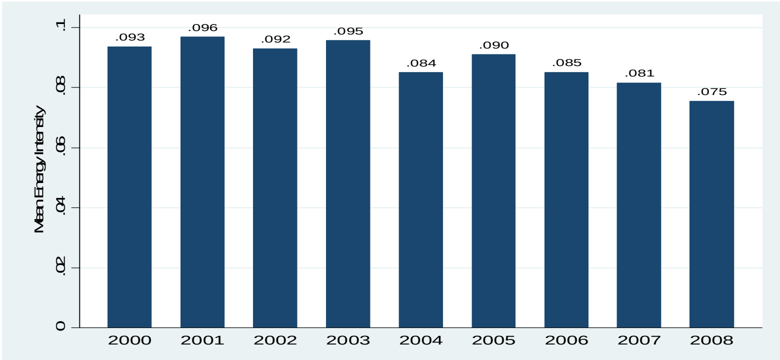

Figure 4: Changes in energy intensity of Indian Manufacturing from 2000-2008

5. Empirical Findings

As mentioned earlier we have used regression model in analyzing firms form 2000-2008. Data for 19 sub-industries of Indian manufacturing industries, from 2000-2008 have been collected. As discussed, we have constructed 11 variables to check its relationship with the energy intensity. Expect the dummy variables; all other variables are in the form of ratios. Given the sample is an unbalanced panel; the number of observations varies across years. The mean of each of the variables (expect the dummies) are presented in Table 3. The changing patterns of the energy intensity from 2000-2008 can be observed from Table 3. It can be observed that there has been a decreasing trend in the energy intensity from 2000 to 2008. From 2000 to 2005, the variation in the energy intensity is fluctuating; however, from 2005 onwards the energy intensity of the sample is declining at a faster rate. Indian manufacturing firms recorded highest energy intensity in 2002 and the least in 2008. Therefore we can assume that these industries are turning to be energy efficient from 2000 to 2008. It is noted that the changes in labour intensity of the manufacturing industries is also declining from 2000 to 2008. However, in the in 2002, the labour intensity is recorded to be highest and the least labour intensity is calculated for 2008.

There is a wide variation in capital intensity as compared to energy intensity and labor intensity from 2000-2008. We can observe that capital intensity is calculated to be highest for 2002, and the least is calculated for 2004. From 2004, the capital intensity of Indian manufacturing is increasing. We can see that in 2001, the repair intensity of the sample is calculated to be the highest, and the least repair intensity was calculated for 2007. In 2001, the research and development intensity was calculated highest for the sample of Indian manufacturing. However, the very next year the intensity reduced and continued to decline till 2005. In 2005, the R&D intensity increased as compared to 2004. The least R&D intensity is calculated for the years 2000 and 2002 respectively. The mean changes in technology import intensity can be observed from Table 3. It can be observed that in 2000, this intensity was calculated to be the highest however; from 2001 to 2005 the technology import intensity has remained at a steady state and decreased in 2006. From 2006-2008 the intensity has again remained unchanged.

Table 3: Mean of different variables from 2000-2008

Variables	2000	2001	2002	2003	2004	2005	2006	2007	2008
Energy Intensity	0.080	0.088	0.081	0.083	0.071	0.075	0.071	0.066	0.061
Labour Intensity	0.130	0.126	0.157	0.117	0.091	0.110	0.085	0.090	0.087
Capital Intensity	4.043	3.617	4.696	4.256	2.040	3.213	2.830	3.439	2.544
Repair Intensity	0.008	0.012	0.008	0.009	0.008	0.008	0.009	0.007	0.008
R&D Intensity	0.002	0.034	0.002	0.002	0.002	0.002	0.005	0.002	0.003
Profit Margin	-0.60	-0.79	-0.94	-0.40	-0.12	-0.02	-0.17	-0.12	-0.13
Size of the firm	1.496	1.513	1.553	1.609	1.550	1.626	1.736	1.839	1.979
Age of the firm	32.58	32.37	32.77	33.06	34.38	34.59	31.68	31.41	32.01
No of Observations	3770	3479	3892	3583	4701	4183	3722	3418	2781

Source: Own estimates from PROWESS database, CMIE

The descriptive statistics of the full sample from 2000 to 2008 is given in Table 4. The mean technology import intensity lies at 0.089 with a maximum value of 10.00. The mean labor intensity of the sample is 0.12. The potential data consists of higher labor as well as least labor intensive firms. The mean capital intensity of the firm is calculated to be 3.93 from 2000-2008. As in case of the labor intensity the sample consists of higher as well as lower capital intensive firms. The mean repair intensity and the R&D intensity are calculated to be 0.01 & 0.007 respectively. Given the heterogeneity of the firms in nature there are firms with high profit as well as with negative profit margin. The mean profit margin is calculated to be -0.43, however the lowest profit margin is calculated to be at -1400.00 and the highest at 1171.50. Mean firm size is calculated to be 1.59, with the smallest firm size of -2.0 and the largest firm size of 5.16. The mean age of the potential data set is calculated to be 33.41, where the minimum age of the firm is as young as one year and the maximum age is as old as 182 years.

Table 4: Descriptive statistics of the sample

Variables	Mean	Standard Deviation	Minimum	Maximum
Energy Intensity	0.0890	0.1833	0.0100	10.0000
Labour Intensity	0.1222	1.0287	0.0001	129.9286
Capital Intensity	3.9321	74.9079	0.0004	6440.0000
Repair Intensity	0.0102	0.0725	0.0004	8.0000
R&D Intensity	0.0071	0.7510	0.0000	125.6000
Technology Import Intensity	0.0002	0.0057	0.0002	0.8333
Profit Margin	-0.4345	13.7714	-1411.0000	1171.5000
Size of the firm	1.5916	0.8055	-2.0000	5.1642
Age of the firm	33.4131	65.4807	2.0000	182.00
No of observations	28120			

Source: Own estimates from PROWESS database, CMIE

Table 5 presents the correlation matrix. From the table it can be seen that the correlation coefficients in few cases are turned out to be very small. The correlation coefficients between energy intensity and labour intensity, capital intensity, repair intensity, R&D intensity, and age of the firm are turned out to be positive. Hence, we can assume that a positive change in the energy intensity will turn out to positively relate the above variables and there is a unidirectional relationship between the energy intensity and the other variables. However, the correlation coefficients between energy intensity to technology import intensity, profit margin, and size of the firm have turned out to be negative. That means that there is a negative relationship between the energy intensity and the rest of the variables.

Table 5: Correlation matrix

Variables	EI	LI	CI	RI	RDI	TECH	PM	SIZE	AGE
EI	1.00								
LI	0.33	1.00							
CI	0.42	0.28	1.00						
RI	0.33	0.11	0.12	1.00					
RDI	0.11	0.01	0.10	0.00	1.00				
TECH	-0.01	0.00	0.00	0.02	0.00	1.00			
PM	-0.23	-0.26	-0.60	-0.11	-0.07	-0.01	1.00		
SIZE	-0.16	-0.09	-0.09	-0.04	-0.01	-0.01	0.08	1.00	
AGE	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.04	1.00

Number of observations: 28120; Source: Own estimates from PROWESS database, CMIE

Using data from 2000-2008, we have estimated regressions equation following equation-1.. We have used as many specifications as possible; however, the best result is presented as the empirical estimates. As the panel suffers from hetroscadasticity problem, as a correction to that the estimation is based on the robust standard errors. Table 6 summarizes the finding of the estimation. Although R2 is rather low at 36 percent, it is reasonable given the large heterogeneous panel of firms covered in the sample. The F statistics and the DW test statistics have turned out to be highly significant.

From the empirical results of the estimated regression to determine the factors influencing energy intensity, it is found that the labor intensity has turned out to be positive and insignificant. That means labor intensity probably does not seem to be affecting the energy intensity of the firms. Subrahmanya (2006) found a positive relationship while studying labor efficiency in promoting energy efficiency and economic performance with reference to small-scale brick enterprises cluster in Malur, Karnataka State, India. The Capital intensity is found to be an important determinant of energy intensity (positive and significant at 1% level). That means the capital intensive firms are energy intensive too. Papadogonas et al. (2007) found similar results for Hellenic manufacturing sector where they reported that capital-intensive firms are energy intensives.

The repair intensity has turned out to be positive and statistically significant which is in accordance with our hypothesis. This means firms those are occurring higher expenditure on repair of machineries, are the most energy intensive ones. The research & development intensity of the firm turned out to be positively significant.

Table 6: Determinants of energy intensity of Indian manufacturing industries

Explanatory Variables	Coefficient	Robust Standard Errors	t value
Labour Intensity	0.035	0.023	1.480
Capital Intensity	0.001	0.000	2.800***
Repair Intensity	0.664	0.206	3.220***
R&D Intensity	0.018	0.003	6.510***
Technology Import Intensity	-0.392	0.065	-6.020***
Profit Margin	0.001	0.001	0.990
Size of the Firm	-0.079	0.015	-5.430***
Square of the Size of the Firm	0.019	0.004	4.950***
Age of the Firm	0.000	0.000	2.100***
Square of the Age of the Firm	0.000	0.000	-2.280***
Industry Dummy	-0.020	0.012	-1.700*
Firm Dummy	0.081	0.001	61.320***
Constant	0.094	0.018	5.250
Number of Observations		28120	
F(12, 28107)		3020.55***	
R-squared		0.36	
Durbin-Watson d-statistic (13, 9)		2.54	

***: Significant at 1% level, **: Significant at 5% level, *: Significant at 10% level
Source: Own estimates from PROWESS database, CMIE

Which in turn mean higher the R&D intensity, higher the energy intensity? This argument does not hold scientifically true as higher innovative research and development expenses of firms should help firms to be energy efficient. However, as data at the firm level don't classify the nature of R&D whether for the product innovation/up-gradation or for developing greater technologies for energy saving equipments, we can assume that firms those invest on R&D might focus on product and or process development rather R&D in energy saving technologies. This argument leads to the question of relating the nature of the R&D in Indian manufacturing and energy intensity changes. A partial answer to the above discussion on the relationship between R&D intensity and energy intensity the estimates of technology import intensity. It is interesting to note that, the technological import intensity is turned out to be negatively related with the energy intensity and statistically significant at 1%. Therefore, we can assume that, firms import highly sophisticated technologies, which lead to lesser use of energy per unit of production. Hence, it is evident from the result that higher the technology import intensity of firms lesser the energy intensity and hence higher energy efficiency. A positive relationship is found between profit margin and energy intensity however, the result is not statistically significant.

The coefficient of firm size is found to be significant and negative and the coefficient of square of the firm size found to be significant and positive. This indicates that energy intensity is higher for firms which are smaller in size and lower for the larger firms. Hence, we found a nonlinear (U shape) relationship between energy intensity and firm size. Hence, it can be assumed that bigger firms are more energy efficient as compared to the smaller firms after a point of threshold. The coefficient of the age of the firm is found to be significant and positive and the coefficient of the square of the age of the firm found to be significant and negative. This indicates that that energy intensity is higher in case of the firms which are older and lower for the younger firms. Hence, there is an inverted U shape relationship exists between energy intensity and the age of the firm. Therefore, it can be assumed that younger firms are more energy efficient compared to the older firms. This means the new firms are probably adopting energy saving technologies compared to the older firms and older firms have energy cost advantage as compared to younger firms. The Industry dummy capturing the effect of MNE affiliation has a significant negative effect on the energy intensity (at 10% level). This suggests that foreign owned firms are efficient as compared to the domestic ones. The firm dummy has turned out to be positive and highly statistically significant. This means, the energy intensity is higher for the industries those consume more energy as compared to the industries which are consuming less.

6. Summary and Conclusion

The increasing concern on climate change, green house gases emission, and demand for energy are matter of concern not only for developed countries but also for the developing and less developed countries. India which is one of the largest and rapidly growing developing countries the issue of energy intensity needs special focus in research and policy front. However, the discussion on the energy intensity should not be restricted at the aggregate/national level. Specific analysis must be carried out for the sub-sectors as well. In this connection, this work is an attempt to understand the factors determining the changing energy intensity in Indian manufacturing industries using data from 2000-2008. Energy intensity in Indian manufacturing industries is a matter of concern given the high import burden of crude petroleum. Concerns have been reinvigorated by the global and local environmental problems caused by the ever-increasing use of fossil fuels, and so it is clearly an enormous challenge to fuel economic growth in an environmentally sustainable way. In this context, this paper has analyzed the determinants and inter-firm differences in energy intensity of Indian manufacturing.

The study observes technology imports are among the important contributors in declining the firm-level energy intensity and hence increasing the energy efficiency of the firms. The analysis highlights that foreign ownership is also an important determinant of energy intensity of Indian manufacturing. Results confirm that foreign ownership leads to higher energy efficiency. Hence there might be presence of significant energy efficiency spillover from foreign firms in such industries to local firms. Evidently there are externalities from foreign investment in energy intensive industries, and such investment therefore needs encouragement and policy support. We found a nonlinear (U Shape) relationship between energy intensity and firm size. Further, this study found that capital and labor intensive firms are also energy intensives ones. Hence, in policy front fiscal incentives could directed more to firms who import technology in order to reduce energy intensity and also encourage foreign technical collaborations to adapt environmentally benign and energy saving technologies.

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