Determinants of Energy Intensity in Indian Manufacturing: An Econometric Analysis

Santosh Kumar Sahu[*] & K. Narayanan[Φ]

Abstract

The demand for energy, particularly for commercial energy, has been growing rapidly with the 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. In this context the energy intensity are the key factors, which affect the projections of future energy demand. Energy intensity in Indian industry is among the highest in the world. The manufacturing sector is the largest consumer of commercial energy in India. Energy consumption per unit of production in the manufacturing of steel, aluminum, cement, paper, textile, etc. is much higher in India, even in comparison with some developing countries. In this study we attempt to analyze energy intensity at firm level and define energy intensity as the ratio of energy consumption to sales turnover. The purpose of this study is to understand the factors that determine industrial energy intensity in Indian manufacturing. The results of the econometric analysis, based on firm level data drawn from the PROWESS data base of the Centre for Monitoring Indian Economy during recent years, identify the sources of variation in energy intensity. Also, we found a non-linear 'U' shaped relationship between energy intensity and firm size, implying that both very large and very small firms tend to be more energy intensive. The analysis also highlights that ownership type is an important determinant of energy intensity. We found that foreign owned firms exhibit a higher level of technical efficiency and therefore are less energy intensive. The technology import activities are important contributors to the decline in firm- level energy intensity. The paper also identifies that there is a sizable difference between energy intensive firm and less energy intensive firms. In addition the results shows that younger firms are more energy efficient as compared to the older firms and an inverse U' shaped relationship is found between the energy intensity and the age of the firm.

JEL Codes: Q4, B23

Keywords: Energy Intensity, Commercial Energy Consumption, Indian Manufacturing Industries

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 (EIA, 2006[1]). Energy use in developing countries has risen more than fourfold over the past three decades and is expected to increase rapidly in the future (EIA, 2006[2]). Number of factors influence energy requirement of an economy, with economic growth being the most important factor. Economic growth is often accompanied by industrialization, electrification, and rapid growth

[*] Doctoral Student, Department of Humanities & Social Sciences, Indian Institute of Technology Bombay, Mumbai, India, santoshks@iitb.ac.in

[Φ] Professor of Economics, Department of Humanities & Social Sciences, Indian Institute of Technology Bombay, Mumbai, India, knn@iitb.ac.in

[1] http://tonto.eia.doe.gov/country/country_energy_data.cfm?fips=IN

[2] ibid

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 in an economy. Higher income levels can lead to the development and diffusion of more technologically sophisticated, but less energy intensive, machines. One of the most significant energy-related changes in the last 20 years has been the significant reduction in energy intensity in the world's developed countries. Between 1980 and 2001, the OECD's energy intensity declined 26%; the Group of Seven's (G-7[3]) fell 29%; and the U.S.' dropped 34% (IEA, 2007[4]).

Recently published work (Van, 2008[5]) 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 (as shown by most of the earlier studies based on parametric estimation). Further the results suggest that there will be a serious challenge to economic and environmental problems in developing countries like 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) hypothesis, rather predicts that energy consumption will rise with rise in income at an increasing rate for low income countries then at a stabilize rate for high income countries. In addition, the study depicts rapid increases 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 (CO^2).

India is a developing country with more than a billion population. There has been a rapid rise in the use 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[6]). Energy intensity is an indicator that shows how efficiently energy is used in the economy. The energy intensity of India is over twice that of the matured economies, which are represented by the OECD[7]

[3] This group known as the G-7, includes Japan, West Germany, France, Britain, Italy, Canada and the United States. Organized in 1986.
[4] www.iea.org
[5] Van, 2008, http://www.u-cergy.fr/thema/repec/2008-03.pdf
[6] ibid
[7] Organization of Economic Co-operation and Development

member countries (IEA, 2007). However, since 1999, India's energy intensity has been decreasing and is expected to continue to decrease (Planning Commission, 2001[8]). These changes could be attributed to several factors, some of them being demographic shifts from rural to urban areas, structural economic changes towards lesser energy industry, impressive growth of services, improvement in efficiency of energy use, and inter-fuel substitution.

Energy intensity in Indian industries is among the highest in the world. The manufacturing sector is the largest consumer of commercial energy compared to the other industrial sectors in India. In producing about a fifth of India's GDP, this sector consumes about half the commercial energy when the total commercial energy for industrial use in India is taken in consideration. Energy consumption per unit of production in the manufacturing of steel, aluminum, cement, paper, textile, etc. is much higher in India, even in comparison with other developing countries (GoI, 2007).

Number of studies has been conducted in Total Factor Productivity (TFP) and Technical Efficiency in Indian Manufacturing (Mitra et al; 1998; Golder, 2004) in India. Studies have also pointed out the TFP of energy intensive industries in Indian manufacturing industries (Puran & Jayant, 1998). Many other studies have also been conducted to study variation in R&D intensity in Indian Manufacturing sector at the aggregate and disaggregate levels (Kumar; 1987); and determinants of R&D in Indian Industries (Narayanan and Banerjee, 2006; Kumar and Saqib; 1996, Siddharthan and Agarwal 1992). Demand for energy in Indian manufacturing industries for aggregate level as well as for specific industries, are also being of much interest to the energy researchers in India (Saumitra, and Rajeev, 2000). However, very few research efforts have been devoted to examine the determinants of Energy Intensity in Indian Manufacturing sector. Therefore, there is a need to study the determinants of energy intensity of Indian manufacturing and to analyze the factors affecting the energy intensity. With this motivation, this study is a preliminary investigation to the determinants of energy intensity of Indian Manufacturing. This study attempts examine the relation of firm-level energy intensity with firm-level economic characteristics. The organization of the study is as follows. Section 2 of the study attempts to look at the existing review on the industrial energy consumption. In section 3, we have narrated the methodology, data sources, and hypotheses of this study. Section 4 summarizes of key ratios of the Indian manufacturing industry at

[8] planningcommission.nic.in/plans/planrel/fiveyr/welcome.html

aggregate level. The empirical finding of the study is discussed in section 5. The summary and conclusion of the study is described in Section 6.

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, many of the research has been carried out to find out the relationship between energy consumption and climate change issues. However there are few studied which indicate the energy intensity for industry specific. In this context, study by Vanden, and Quan, (2002) for China is relevant. They have employed approximately 2,500 large and medium-sized industrial enterprises in China for the period 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 and changes in ownership, region, and industry composition are less important. The association between differences in relative energy prices and measured energy intensities indicated that Chinese firms are responding to prices- something not largely observed in the past. In addition, the impact of R&D spending on energy intensity suggested that firms are using resources for energy saving innovations.

However, as indicated earlier a very large number of studies dealing on energy demand of the production sector have been published. Generally, we can divide these studies in two broad categories. The first category focuses on the demand for various types of energy, which yields information about substitution possibilities between energy inputs say electricity and coal. The examples are Griffin (1977), Halvorsen (1977), and Pindyck (1979). The other category focuses on substitution between energy and other factors like labour, capital, and materials. The examples include Griffin and Gregory (1976) and Berndt and Wood (1975).

Both categories of models are typically estimated by a system of factor demand equations derived from cost minimization firms using translog cost function. Andersen et al. (1998) obtain price elasticity at -0.26 for the manufacturing sectors energy demand and the aggregate elasticity for various industrial sub-sectors ranges between -0.10 and -0.35. Thomsen (2000) obtains price elasticity at -0.14. Both results are obtained by estimation of a system of factor demand equations using the Generalized Leontief Functional form.

Woodland (1993) uses cross-section data for about 10,000 companies in the years 1977-85 from the Australian state of New South Wales. The study uses a translog system with coal, gas, electricity, oil, labour, and capital included as production factors. Woodland observes that only a minor share of the companies have an energy pattern, where they 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) look at a panel of Dutch firms from 1978-86 also using the translog functional form focusing on aggregate energy demand. The long-run price elasticity of energy for the whole manufacturing sector in their study is -0.56, while the long-run output elasticity is 0.61. Kleijweg et al. subsequently analyze subsets of data divided by firm size, energy intensity, and investment level. They find that the own price elasticity of energy increases with firm size, and to a lesser extent that the price elasticity decreases with energy intensity and increases with the level of investments. However, these findings are derived from separate estimations and therefore do not take into account correlation between firm size, level of investment and energy intensity.

In an attempt to find out the demand for energy in Swedish Manufacturing industries Dargay et al (1983), employed a Translog Cost Function (both Homothetic and Non-Homothetic) for 12 manufacturing sub-sector in Sweden 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, his findings suggest that rising energy prices can to some extent, be absorbed by substitution away from energy. The predominance of energy-capital complementarily at the branch level implies, however, that 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, the United Kingdom and the United States from 1970 to 1992. The variables used in their study are Total Energy Consumption, Energy Consumption by sector, Total Industrial production, Production of different sectors, Production share to total production per sector, Energy Output ratio, and Energy intensity. The results from the examination of changes in energy intensity indicate the potential role of the costs of energy and costs of other factors of production as well as economic growth on the evolution of trends of aggregate energy intensity.

In order to examine the Sector 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 decomposition based on changes in industrial energy consumption and that based on changes in aggregate energy intensity and the variable used in his study includes Energy consumption, total output, and energy intensity. His findings suggest the impact of structural change can be large in energy demand projection even if this is made based on simply extrapolating the historical sectoral production growth trends.

Mongia et al (2001) have reviewed the policy reforms and the productivity change in the energy intensive industries in Indian context. Using a four input (KLEM) model they have employed a decomposition analysis of growth of outputs and a residual representing the total productivity growth in case of the Indian manufacturing (energy intensive). They found that the overall productivity growth of these industries have gone down from 1973-1994; however, they found a significant difference in productivity growth across industries during the study period. Taking the study in consideration in studying the role of energy as an input to the production function has a broader scope. As found in their study that the output growth changes in the Indian manufacturing has gone down, but the output growth in the energy intensive industries has a significant difference from the entire manufacturing industries. In this point forward we realize that the role of the energy as an important input in the production function framework. In case of the energy intensive industries, the consumption of the energy resources are higher compared to the other manufacturing industries as found in the literature. 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 selected energy intensive industries. From the discussions above, we can now assume that industries, which are more energy intensive (consuming more of energy for the production process), are better off in the production of the output for Indian manufacturing.

Teteca (1996) has given an extensive review of literature on the environmental performance of the firms taking the desirable and undesirable outputs. In a more simplified terms we can address the outputs as the positive and the negative externalities of the firms. In the work, he has taken the productive efficiency where three factors of production are taken in consideration. He has argued that the previous econometric or DEA analysis have not been able to address the issue. He has employed the DEA analysis in understanding the issue with a non-parametric approach. The existing approaches found in the literature are the followings:

- Life cycle assessment and analysis
- Business specific models- environmental accounting
- Pollution performance index

The discussion in the paper has covered the major work carried out in understanding the earlier works on the environmental performance of the firm. However, he has tried to work in both parametric and the non-parametric approaches in the DEA analysis. He concludes arguing that energy pricing is one of the major questions in the performance of the firm. Hence, there is a need in understanding the energy efficiency of the firms, which will give policy makers and the researchers to understand the efficiency parameters of the firms, which in turn will give ample scope in studying the production function structure as well as studying the ideal production frontier and the resulted production function. There in studying the methodological issues as well as the finding the distance demand function to check the environmental performance of the firms.

3. Methodology Data sources and Hypotheses

Energy intensity is often used as a measure of the efficiency with energy resources is being used. 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. As is well known and widely noted, trends in energy intensity many not reflect underlying trends in technical efficiencies, but instead may reflect such factors as changes in the structure of industry. A decrease in energy intensity may reflect the fact that producers on an average are becoming more efficient at producing finished good. Energy efficiency is normally measured as the ratio of energy consumption to output (for example, Farla et al (1998), Han et al (2007), Young (2007), which is also used to measure energy intensity.

In an earlier attempt we have studied the determinants of energy intensity of Indian manufacturing as an experimental study at a cross sectional data for 2007[9]. Using an

[9] Sahu, Santosh, K., K, Narayanan., (2009), "Determinants of Energy Intensity: A Preliminary Investigation of Indian Manufacturing Industries", Paper presented in the 44th Annual Conference of "The Indian Econometrics Society", at Guwahati University, Assam, India & Available at http://mpra.ub.uni-muenchen.de/16606/

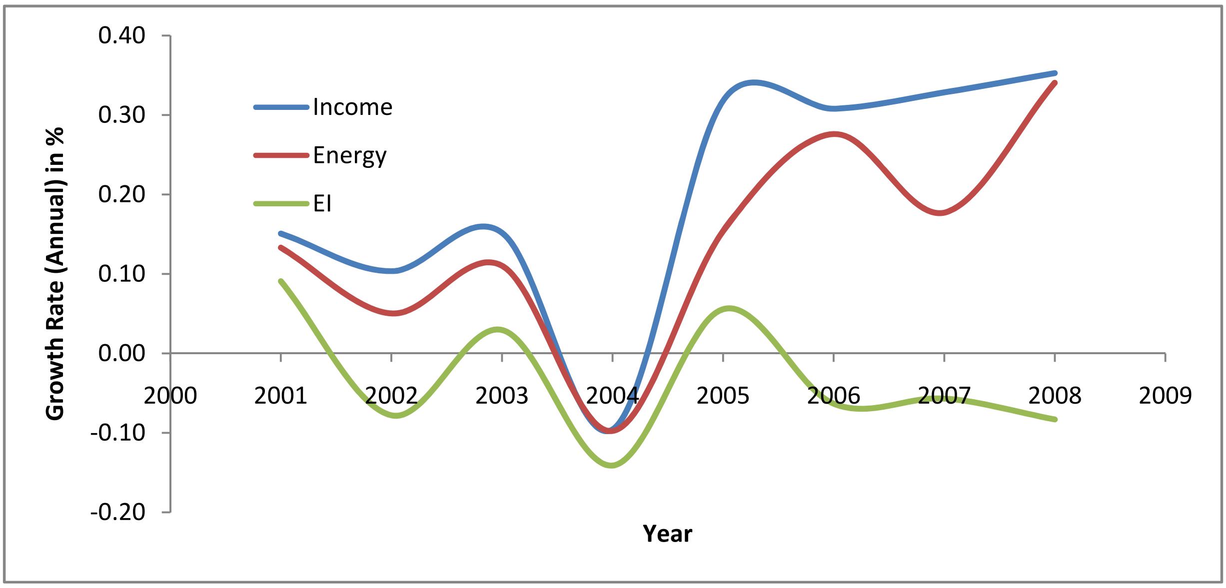
econometric approach that identifies source of variation in energy intensity, we found a positive relationship between energy intensity and firm size, and an inverse U shaped relationship between energy intensity and size of the firm. Our analysis also brings out the finding that ownership type is also an important determinant of energy intensity. We found that foreign owned firms exhibit a higher level of technical efficiency and so is less energy intensive. Further, the results of the study reveal that R&D activities are important contributors to the decline in firm-level energy intensity. We also identified that there is a sizable difference between energy intensive firm and less energy intensive firms.

The present study analyzes the determinants of energy intensity of Indian manufacturing sector, which is an improvement, to the earlier study[10] presented above. The improvements are based on the improvements in the definitions of the variables and using the panel data for the Indian manufacturing. The analysis is carried out using data for a sample of industrial firms. Multiple regression equation is estimated for panel data of nine years, for analyzing the determinants of Energy intensity. The data for the analysis has been drawn from the online Prowess Data Base (as on September 2009) of the 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 analysis. Let us observe the Indian manufacturing output and the energy consumption pattern from 2000-2008. This will give us an idea of the nature of changes in the energy consumption and the production trend in the Indian manufacturing. Figure 3.1; give the changes in annual growth in energy consumption and the output over period of time. It can be seen that the change in output and energy are fluctuating from 2000 to 2008. One major relation can be seen from the figure that the changes in output is more than that of the change in the energy consumption. However, the negative growth in the output and the negative growth in energy are not falling in a same pattern. In 2004 the negative growth in output can be seen, however the negative growth is not that sharp in energy consumption as seen in changes in the output of Indian manufacturing. However, we can see that the direction of the changes in output as well as energy consumption are following a same way. It should be noted that we have tried to draw the changes in the both the variable on the changes on the actual data. When the intensity is drawn in the same diagram, we can see that the changes in the energy intensity of the Indian manufacturing are even following the same direction but the growth rate is much lower than that of the changes in the output growth and the energy consumption growth. As discussed by many researchers

[10] Ibid

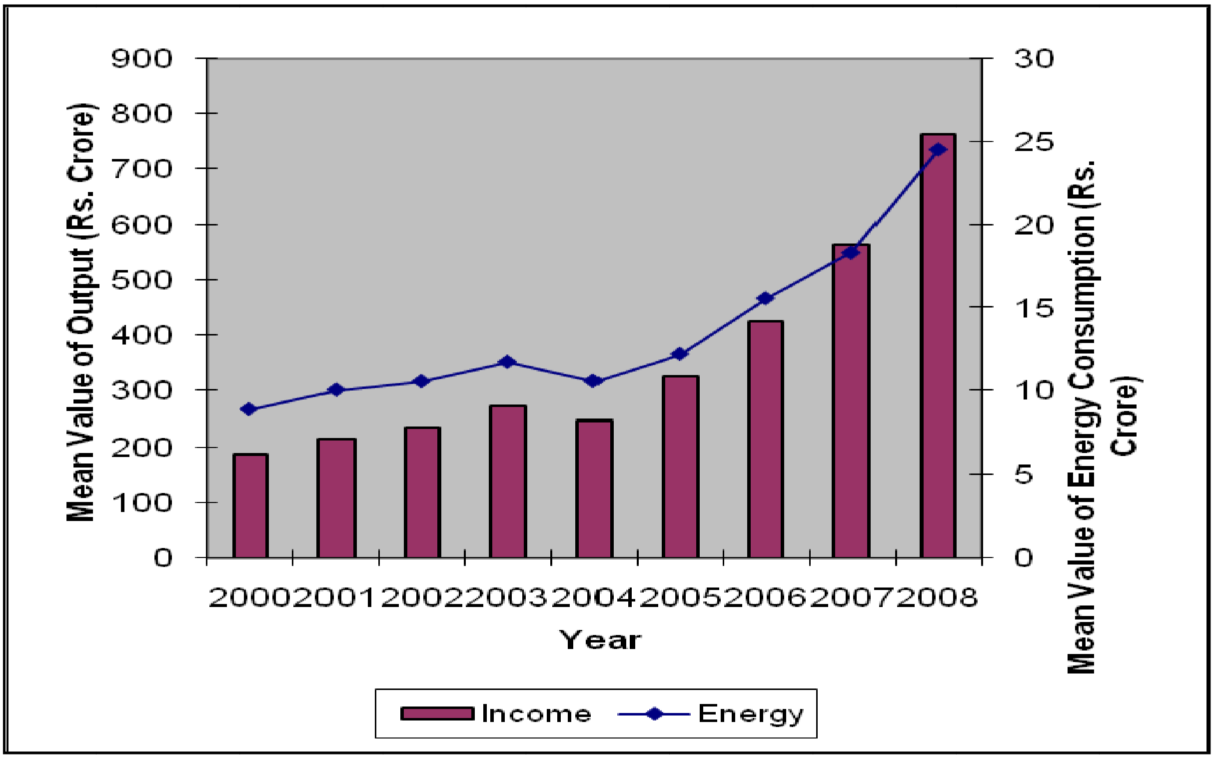
in the energy economics literature as well as particularly in the demand for energy in industries, the energy intensity changes accounts the effectiveness of the use of the energy per unit of output. The basic idea of drawing such relations between the three variables as changes in the growth is to see whether the changes in the productivity of the firms (changes in the output as a proxy) has any relationship on the change in the energy consumption of the firms.

Figure 3.1: Annual Growth rate of output, energy consumption & energy intensity in Indian manufacturing from 2000-2008



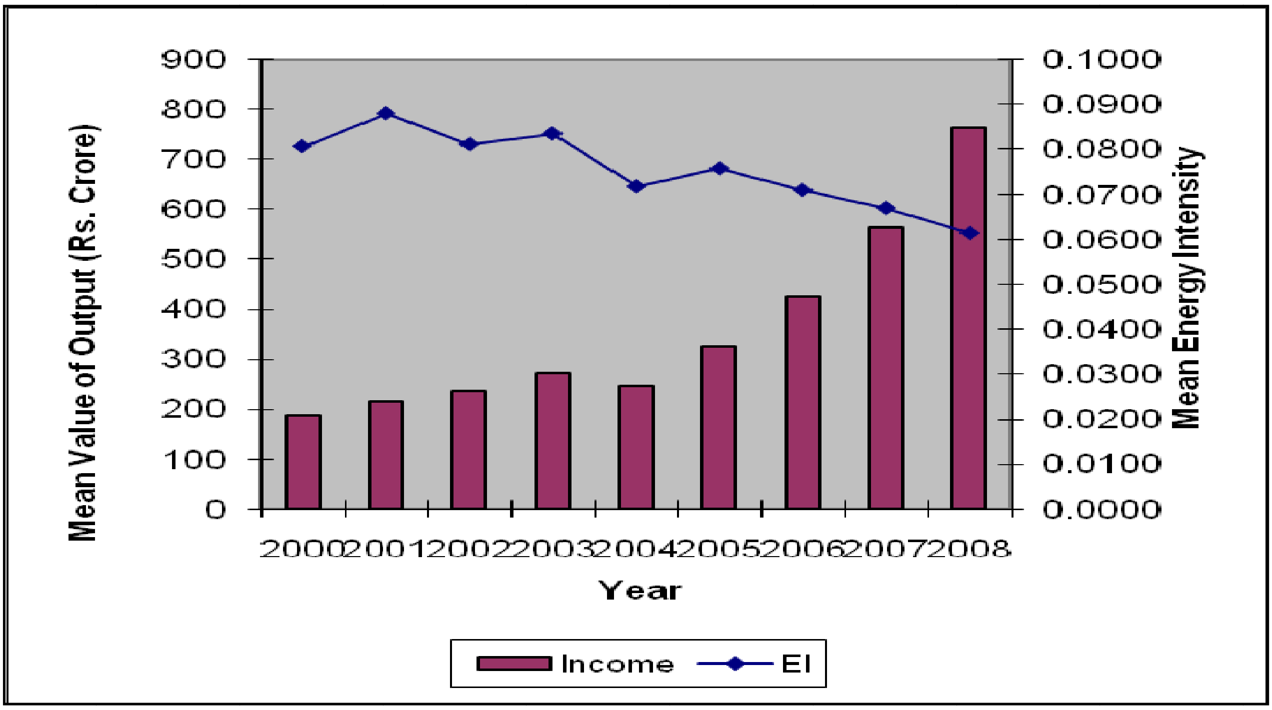
Now the question arises, why to take another variable i.e., the energy intensity? This is due to verify whether the energy consumption is a better explanation compared to the energy intensity, when output taken in consideration. Using many decomposition techniques it has been proved that the energy intensity changes are due to either the sectoral changes in energy intensity or due to the change in the structure of the economy. Hence its more of a discussion what happens in a firm level? To account for this question we have tried to see the changes in the three variables (output, energy consumption & the energy intensity) of the Indian manufacturing by normalizing the values (as they widely differ each other) by taking on the logarithmic scale. Figure 3.2 and 3.3, present the behavior of the three variables from 2000-2008. We can observe that the log of output as well as the log of energy consumption are following the same direction. When the output value increases, there is a change in the energy consumption for the Indian manufacturing also. Nevertheless, at the same time if we observe the pattern of the energy intensity that follows a different direction. In case of the figure 3.1 the growth rates are moving in an equal direction, however the real observations of the three variables in the logarithmic scale are different. It has been noticed that the energy intensity of the Indian manufacturing is declining over the period given the fact that the output changes and the energy consumption are increasing. Hence, the efficiencies in terms of energy use of the Indian manufacturing is increasing.

Figure: 3.2: Mean Changes in output, and energy consumption of Indian manufacturing from 2000-2008



From the above discussion is can be hypothesized that energy intensity a better explanation of the firm characteristics compared to the energy consumption. In this work we are not following the production function approach in order to examine the role of the energy consumption in the production function system; neither are we examining the energy dependent production function. Rather the discussion here is quite interesting and less explored in the energy economics as well as in the industrial economics literature. Here we are more interested in examining the determinants of energy intensity in Indian manufacturing given the role of the energy intensity at the firm level as well. There are lots of factors can influence the energy intensity of the firm. However, based on our previous work on the cross-sectional study and few other studies we have selected the most important variables those influence the energy intensity at the firm level of Indian manufacturing. The arguments are given in the following discussion.

Figure: 3.3: Mean Changes in output, and energy Intensity of Indian manufacturing from 2000-2008



Increases in energy efficiency may take place when either energy inputs are reduced for a given level of service 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 enterprise. The technology imports are likely to affect the energy intensity. By technology import, we mean the payments for imported technology, which include payment of technical fee, lump-sum payments for technology imports, payment of royalty to the foreign collaborator firms for using their trademarks, brand name. Whether these innovation activities lead to product or process innovation, they may have measurable effect on energy intensity. The reason for considering age of the firm is the firms having long span of years in production would likely incur relatively more expenditure on R&D compared to younger firms and hence age of the firm may effect the energy intensity of the firm. Different types of industries use different technologies and the production structure differs and hence, that exhibit different levels of energy intensity. To capture the intra-industry changes in energy intensity three dummies are created for the higher energy intensive, moderate energy intensive and the lower energy intensive industries. To model out the relations we have used the standard econometric approach for the panel data on Indian manufacturing. Basically our current idea is to look at the Indian manufacturing at firm level for the entire manufacturing. Hence, we have not classified the industries and analyzed. We have used the multiple regression model technique to analyze the data. The study uses the following list of variables (given in table 3.1) in the regression model for empirical analysis. The regression equation takes the following functional form:

$$\begin{aligned}(energy\,\mathrm{int}) &= \alpha + \beta_1 capital\,\mathrm{int} + \beta_2 labour\,\mathrm{int} + \beta_3 repair\,\mathrm{int} + \beta_4 rd\,\mathrm{int} + \\ &\beta_5 tech\,\mathrm{int} + \beta_6 profit\,\mathrm{int} + \beta_7 size + \beta_8 size^2 + \beta_9 age + \beta_{10} age^2 + \\ &\beta_{11} industrydummy + \beta_{12} firmdummy + u_i\end{aligned} \tag{3.1}$$

Where: *energy*int: Energy Intensity, *capital*int: Capital Intensity, *labour*int: Labour Intensity, *rd*int: Research Intensity, *tech*int: Technology Import Intensity, *profit*int: Profit Margin of the firm, *size*: Size of the Firm, $size^2$: Square of the size of the firm, *age*: Age of the firm, age^2: Square of the age of the firm, *industrydummy*: A dummy used for the firm if it's foreign owned, *firmdummy*: A dummy used for the firm if its highly energy intensive

Table 3.1 Definition of the Variables used in the study and their expected signs

Sl. No	**Variable**	**Definition**	**Expected Sign**
1	Energy Intensity	The energy intensity is defined as the ratio of the power and fuel expenses to sales	
2	Labour Intensity	We define the labour intensity as a ratio of the wages and salaries to the sales	+ve
3	Capital Intensity	This variable is being measured as the ratio of the total capital employed to the total value of the output	+ve
4	Technology Import intensity	This variable is being calculated as the 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 the sales.	-ve
5	Research Intensity	R&D intensity is measured as the ratio of R&D expenses to the sales.	+ve / -ve
6	Profit Margin	This is taken as the ratio of Profit before tax to sales	+ve / -ve
7	Repair intensity	This variable is being measured as the ratio of total expenses on repairs for plant and machineries to the sales	+ve
8	Size	Size of the firm is measured by the energy consumed in volume. Here we have taken the natural log of the energy consumed by volume to define size of the firm	-ve
9	Age	As a measure of age, we subtract the year of incorporation from the year of the study.	+ve
10	Firm Dummy	This dummy takes the value 0, if the firm is higher energy intensive and one for the rest	+ve
11	Industry Dummy	This dummy takes the value one for the foreign owned firms and zero for the rest	-ve

Hypotheses: Based on the above relations and the discussion the study proposes the following hypotheses to be tested:

- Capital intensity has a positive relationship with the energy intensity
- Repair intensity of firms has positive relationship with the energy intensity of the firms
- Higher the Technology import intensity higher will be the energy intensity as technology imports are followed by further technological effort for absorption of imported knowledge which require more energy
- Foreign firms are expected to be less energy intensive compared to the domestic firms
- Age of the firm has a positive relationship with the energy intensity
- Size of the firm determines the energy intensity over period of time

4. Preliminary Observation of the Industries at Aggregate level and at Firm level

Puran M & Jayant; 1998, have classified the Indian manufacturing industries based on the energy intensity. According to their classification, the major energy intensive industries are Aluminium, Cement, Fertiliser, Glass, Iron and Steel, and Paper and Paper Industries. The energy intensity of the aggregate level data on the Indian manufacturing industries shows that non metallic mineral products industries are the most energy intensive (13.24%), compared to all other eight industries type in study. However, textile industries are second in the high energy intensive category. The machinery industries are the least energy intensive according to the calculation. Another important variable in this study considered to be labour intensity of the firm. The aggregated data for a period of one year shows that miscellaneous manufacturing as the most labour intensive one, which includes; firms on paper & paper products, lather products etc. Chemical industries have resulted to be the less labour intensive. The ratio statistics of different firms in capital intensity shows that the textile industries are the most capital intensive in nature, where as the machinery industries are the less capital intensive. The technology import intensity in the table shows that the textile industries are the most technology import intensive; however, the food and beverages industries are the less technology import intensive in nature. Data shows that the textile industries are the most export oriented and hence the export intensity of this industry is the highest, where as the machinery industries are found out to be the less export oriented. Research intensity of the transport equipment industries has resulted to be the highest among the nine different industries under study. However, the research intensity of the non-metallic mineral industries turned out to be the least in the group. The profit margin of the metals and metal product industries have recorded the highest for the year 2007, however the ratio turned out to be least in case of the textile industries.

The Machinery industry is characterized by lowest energy intensity as well as lowest labour intensity. However, the transport equipment is the most capital intensive, and second from the bottom in case of energy intensity. Chemical industries and the Miscellaneous manufacturing industries are not categorized either side of the scale when the seven key ratios are taken into consideration. Research intensity is found to be the lowest in case of the food and beverages industries. The diversified industries are categorized by lowest capital intensive, lowest technology import intensive as well as lowest export intensive ones. However, metal and metal product industries are found to be more labour intensive as well as least profit makers. The textile industries are the most technology import intensive, research intensive as well as the most export oriented. The non-metallic product industries are found to be the most energy intensive as well most profit makers from the nine industries under study.

The above discussion tries to find out the major key ratios to understand the Indian manufacturing sector at aggregate level as well as to observe the most energy intensive ones. However as the study is focused on determining the factor effecting energy intensity at firm level using firm level data for 2007, the firm level characteristics of the data need to be well described . Therefore, the next section deals with the classification if the industries based on energy intensity. The values in the parenthesis are the value of energy intensity, based on three major classifications (small, medium, and large). The key idea behind this classification is to understand broadly the factor affecting the energy intensity of the industries. The classification given in table 4.1 is not based on industry type; rather we have classified the entire manufacturing data based on the earlier classification for different indicators.

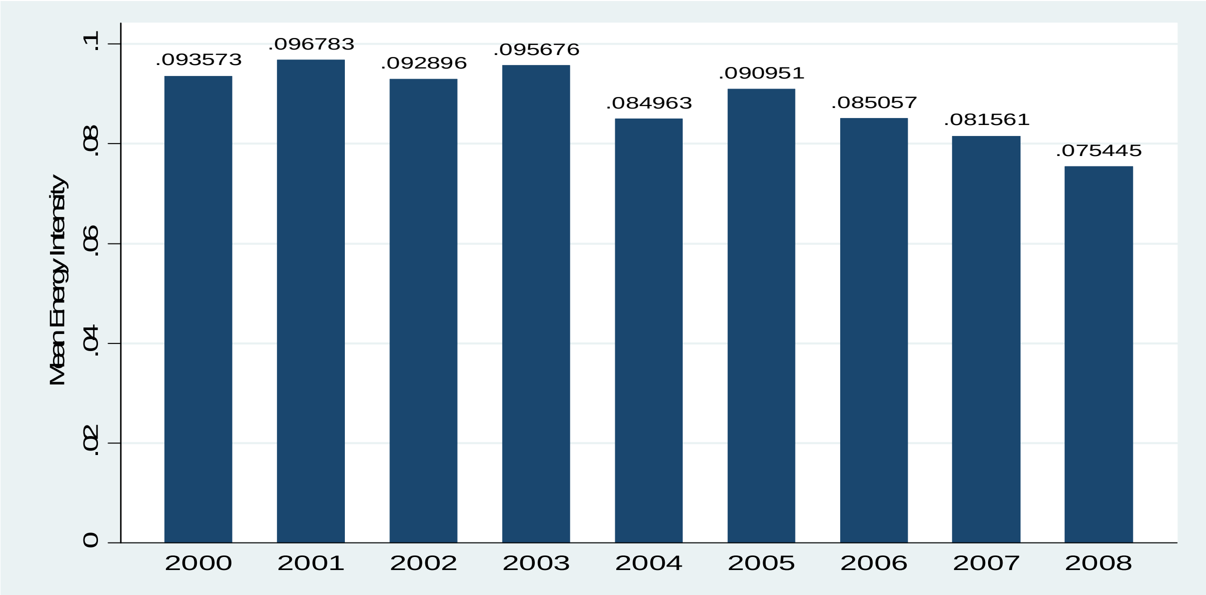
Table 4.1 Classification of industries as per energy intensity and variable characteristics

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 Data Base

From table 4.1, it can be observed that smaller the firm size higher is the energy intensity. It can also be noted that higher the capital intensity of the firms are higher the energy intensity. From the figure, it can be observed that many of the indicators have not shown major variations when classified under energy intensity. Labour intensity has a wider variation while plotting against energy intensity for the three classifications (small, medium, & large). The result in the table shows the labour intensive firms are more energy intensive compared to the less labour intensive ones. Moreover, a clear variation can be observed among the three classifications. Research and development has a major role to play when we discuss the energy intensive of firms. Here the data for the 28,120 firms shows more the research-intensive firms are less energy intensive compared to the less research-intensive firms. However, the relationship is just opposite in case of the technology import intensive firms. The result reveals that the higher the technology intensive firms are more energy intensive and vice versa. In case of the Repair intensity the preliminary results shows that higher the repair intensity, higher is the energy intensity. Profit of the industries may not be directly related to the energy intensity of the firm; however, we suppose that they are indirectly related to the energy intensity of the firms. The preliminary result shows that in both the cases higher is the profit of the firm, lesser is the energy intensity. It has been assumed that Age of the firm has a definite impact on the energy intensity of the firm. The preliminary finding suggests that the medium size firms are more energy intensive and large the age of the firm they are less energy intensive.

Figure 4.1: Changes in energy intensity of Indian Manufacturing from 2000-2008



Let us now look at the changes in energy intensity of the Indian manufacturing from 2000-2008. From figure 4.1, we can see the changing pattern of energy intensity of the Indian manufacturing. The calculated highest energy in the Indian manufacturing was in 2001 and the least energy intensity was found for the year 2008. However, the changes in the energy intensity of the Indian manufacturing are decreasing from 2000-2008.

5. Empirical Findings

As mentioned earlier we have used a panel data econometrics in analyzing the data form 2000-2008. Let us first discuss the nature of data being used for the analysis of the study.

Table 5.1: Characteristics of Data used in the study

Year	**Number of variables**	**Scale**	**Number of sub-industries**	**Sample size**
2000	11	Ratios and dummy (0/1)	19	3770
2001				3479
2002				3892
2003				3583
2004				4701
2005				4183
2006				3722
2007				3418
2008				2781

Table 5.1 describes the characteristics of the panel data. We have constructed 11 variables in analyzing the data. Many of these variables are in the form of ratio. However, the dummy variables are of binary in nature. Data for 19 sub industries have been collected. Given that it is an unbalanced panel data, the number of observations varies according to each year. The mean value of each of the variables (expect the dummies) are presented in table 5.2.

Table 5.2: Mean values of different variables across years

Variables	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Energy Intensity	0.0807	0.0880	0.0812	0.0836	0.0718	0.0758	0.0710	0.0669	0.0614
Labour Intensity	0.1300	0.1268	0.1579	0.1177	0.0915	0.1105	0.0854	0.0902	0.0871
Capital Intensity	4.0432	3.6170	4.6967	4.2560	2.0408	3.2134	2.8309	3.4394	2.5443
Repair Intensity	0.0088	0.0122	0.0085	0.0091	0.0083	0.0083	0.0098	0.0078	0.0081
R&D Intensity	0.0021	0.0346	0.0021	0.0027	0.0022	0.0026	0.0051	0.0025	0.0031
Technology Import Intensity	0.0005	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001
Profit Margin	-0.6011	-0.7902	-0.9401	-0.4008	-0.1237	-0.0298	-0.1740	-0.1245	-0.1342
Size of the firm	1.4963	1.5139	1.5530	1.6096	1.5507	1.6263	1.7364	1.8392	1.9791
Age of the firm	32.5881	32.3718	32.7714	33.0675	34.3876	34.5957	31.6881	31.4166	32.0144
No of Observations	3770	3479	3892	3583	4701	4183	3722	3418	2781

Source: Own estimates from Prowess Data Base

The changing pattern of the energy intensity from 2000-2008 can be observed from the table 5.2. It can be seen that there has been a decreasing trend in the energy intensity from 2000 to 2008 of Indian manufacturing. From 2000 to 2005, the variation in the energy intensity was fluctuating; however, from 2005 onwards the energy intensity of the sample has been declining at a faster rate. The year 2002 has recorded the highest energy intensity and the least energy intensity is found for the year 2008. Hence, the industries are becoming more energy effective from 2000 to 2008. The mean value change in the labour intensity is well described in the table 5.2. It can be noted from the table that the changes in the labour intensity of the manufacturing industries too declining from 2000 to 2008. However, in the in 2002, the labour intensity was recorded at its peak and 2008 recorded the least labour intensity for the Indian manufacturing. There is a wide variation in the capital intensity of the firms as compared to the energy intensity and the labour intensity from 2000-2008. We can observe that the highest capital intensity was calculated for the year 2002, and the least was found for the year 2004. From 2004, the capital intensity of the Indian manufacturing is increasing. Let us now observe at the changing pattern of the repair intensity of the sample.

We can see that in 2001, the repair intensity of the sample was calculated to be the highest, and the least repair intensity was calculated for 2007. In the year 2001, the Research and Development intensity was calculated highest for the select sample of Indian manufacturing. However, the very nest year the ratio came down and continued until 2005. In 2005, the R&D intensity found to be increased compared to 2004. The least R&D intensity was calculated for the years 2000 and 2002 consecutively. The technology import intensity of the Indian manufacturing has a different picture all together. The mean changes in the technology import intensity can be observed from table 5.2. It can be observed that in 2000, the intensity was calculated to be the highest, however, from 2001 t0 2005 the technology import intensity has remained at a steady state and decreased in 2006. However, from 2006-2008 the intensity value has again remained unchanged. The descriptive statistics of the entire sample from 2000 to 2008 is given in table 5.3.

Table 5.3 Descriptive Statistics of the Sample

Variables	**Mean**	**Std. Dev.**	**Min**	**Max**
Energy Intensity	0.0890	0.1833	0.0100	10.0000
Labour Intensity	0.1222	1.0287	0.0000	129.9286
Capital Intensity	3.9321	74.9079	0.0004	6440.0000
Repair Intensity	0.0102	0.0725	0.0000	8.0000
R&D Intensity	0.0071	0.7510	0.0000	125.6000
Technology Import Intensity	0.0002	0.0057	0.0000	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
Industry Dummy	0.9690	0.1733	0.0000	1.0000
Firm Dummy	0.7505	0.4327	0.0000	1.0000
No of observations	28120			

Source: Own estimates from Prowess Data Base

The mean technology import intensity lies at 0.089 with a maximum value of 10.00. The mean labour intensity of the sample is 0.12, at 0.00 as the minimum labour intensity and 129.90 as the highest labour intensity. Hence, the potential data consists of higher labour as well as least labour intensive firms. The mean capital intensity of the firm is calculated to be 3.93 from 2000-2008 with 0.00 at the lowest and 8.00 at the highest side. Hence as in the case of the labour intensity the sample data consists of higher as well as lower capital intensive firms in the analysis. The mean value of the 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 firms with negative profit margin. The mean profit margin is calculated to be -0.43, however the lowest profit margin is calculated to be -1400.00 and the highest being 1171.50. Mean firm size is calculated to be 1.59, with the lowest firm size at -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.

The abbreviations used for the variables in the subsequent analysis are given in table 5.4. Table 5.5 presents the correlation coefficient between the variables used in the model. From the table it can be seen that the correlation coefficients in few cases are turned out to be small. The correlation coefficient between energy intensity and labour intensity, capital intensity, repair intensity, R&D intensity, Age of the firm and Firm dummy 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.

Table 5.4 Abbreviations Used in the Analysis

Abbreviation	**Name of the Variable**	**Abbreviation**	**Name of the Variable**
EI	Energy Intensity	PM	Profit Margin
LI	Labour Intensity	SIZE	Size of the firm
CI	Capital Intensity	SIZE2	Square of the Size
RI	Repair Intensity	AGE	Age of the firm
RDI	R&D Intensity	AGE2	Square of the Age
TECH	Technology Import Intensity	ID	Industry Dummy
FD	Firm Dummy		

Table 5.5 Correlation Matrix

Variables	**EI**	**LI**	**CI**	**RI**	**RDI**	**TECH**	**PM**	**SIZE**	**SIZE2**	**AGE**	**AGE2**	**ID**	**FD**
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					
SIZE2	-0.08	-0.05	-0.04	-0.02	0.00	0.00	0.04	0.93	1.00				
AGE	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.04	0.05	1.00			
AGE2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.01	0.96	1.00		
ID	-0.03	-0.08	0.00	-0.01	0.00	0.00	0.03	-0.09	-0.11	-0.02	0.00	1.00	
FD	0.54	0.24	0.26	0.17	0.06	0.00	-0.16	-0.16	-0.08	0.01	0.01	-0.02	1.00

No of observations: 28120, Source: Own estimates from Prowess Data Base

However, the correlation coefficient between the energy intensity to technology import intensity, profit margin, size of the firm and Industry dummy have turned out to be negative. That means that there is a negative relationship between the energy intensity and the rest of the variables. The result of the multiple regression model is given in table 5.6 below.

This discussion is pertaining to the estimation of the regression equation. We have estimated regressions equation from the period 2000-2008 using panel. We have used many specifications of the regression equations, however the best results is presented here in the empirical results. As the panel suffers from Hetroscadasticity problem, as a correction to that the estimation is based on the robust standard errors. Table 5.6 summarizes the findings of the estimation. We have used STATA 10.0 MP for estimating the results. Although R-square is rather low at 36 percent, it is reasonable given the large heterogeneous panel of companies covered in the sample. The F statistics and the DW test statistics have turned out to be highly significant. Findings pertaining to the role of different variables are discussed below.

The coefficient of the labour intensity has turned out to be narrative and insignificant. That means labour intensity does not seem to be affecting the energy intensity of the firms. However, as there is a negative relationship found, we can assume that the higher the labour intensive firms are using more energy saving techniques compared to the lower labour intensive firms. Subrahmanya (2006) found out similar result while studying the labour efficiency in promoting energy efficiency and economic performance with reference to small-scale brick enterprises' cluster in Malur, Karnataka State, India. Hence, considering the result obtained, improvement of labour efficiency can be an alternative approach for energy efficiency improvement in energy intensive industries, in developing countries like India.

Age of the firms has turned out to be one of the determinants of the energy intensity of Indian manufacturing firms. The variable is turned out to be positive and statistically significant. Hence, it can be narrated that older the firms in production are more energy intensives. This means the new firms are adopting the energy saving technologies compared to the older firms or large firms have an energy cost advantage in relation to smaller firms.

Table 5.4 Regression Result

Dependent Variable: EI (Energy Intensity)

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	

Note: *** Significant at 1% level,
** Significant at 5% level
* Significant at 10% level

From the empirical results of the estimated regression to determine the determinants of energy intensity, it can be found that the labour intensity is found positively related to the energy intensity of the firms. However, the Capital intensity is found to be important determinants of energy intensity (positive and significant at 1% level). That means that more capital-intensive firms are more energy intensive. Papadogonas et al (2007), found similar result for Hellenic manufacturing sector where they reported that capital-intensive firms too are energy intensives.

The repair intensity variable turned out to be positive and statistically highly significant which is in accordance with our hypothesis. This means firms, which are occurring higher expenditure on the repair of machineries, are the most energy intensive ones. As it can be seen that in the descriptive statistics we have seen that the firms incurred a typical investment similar to each consecutive years. Therefore, the repair intensity has turned out to be one of the major determinants of the energy intensity at firm level.

Surprisingly the research & development intensity of the firm turned out to be positively significant in the model output. Which in turn mean higher the R&D intensity, higher the energy intensity? This argument do not hold scientifically true as higher innovative research and development takes the firms should be energy efficient. However, as data at the firm level don't classify the nature of R&D takes place whether for the product innovation/up-gradation or for developing greater technologies for energy saving equipments, we can assume that firms do R&D, however as the R&D might not be in developing energy saving technologies rather product and or process development of manufacturing more of R&D intensive firms are higher energy intensive too. This arguments leads to another research question in finding out the nature of the R&D takes place in the Indian Manufacturing and its relationship with the energy intensity.

A partial answer of the above discussion on the relationship between R&D intensity and Energy Intensity may be result obtained for the technology import intensity. It is interesting to note that the technological import intensity variable is turned out to be one of the major determinants of energy intensity. The coefficient bears negative relationship with the energy intensity and statistically significant at 1%. Therefore, we can assume that the firms import highly sophisticated technologies, which lead to lesser use of energy for a 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 efficient.

A positive relationship is found between profit margin and energy intensity, which imply that profitability of firm seems to be positively affecting the energy intensity of the firm. However, the result is not statistically significant.

The coefficient of the firm size is found to be significant and negative and the coefficient of square of the size of the firm found to be significant and positive. Thus indicate that that the energy intensity is higher in case of the firms which are smaller in size lower for the larger firms. Hence there is a U' shaped relationship exists between the energy intensity and the size of the firm. Hence it can be assumed that firms of bigger size are more energy efficient compared to the firms which are smaller in size.

The coefficient of the age of the firm is found to be significant and positive and the coefficient of the square of age of the firm sound to be significant and negative. Thus, indicate that that the energy intensity is higher in case of the firms which are older and lower for the younger firms. Hence there is an inverted U' shaped relationship exists between the energy intensity and the size of the firm. Therefore, it can be assumed that younger firms more energy efficient compared to the older firms.

The Industry dummy capturing the effect of affiliation with MNEs has a significant negative effect on the energy intensity as the coefficient has turned out to be negative significant (10% level). That suggests that foreign owned firms are more efficient in their use of energy as reflected in the negative coefficient compared to the domestic ones. The firm dummy has turned out to be positive and highly statistically significant. That means that the energy intensity are higher for the industries those consume higher volume of energy (in turns the energy intensive ones) compared to the industries which are consuming lesser energy or the less energy intensive industries. Therefore, it can be assumed that higher energy intensive industries are less energy intensive compared to the lesser energy intensive industries.

6. Summary and Conclusion

The increasing concern on Climate Change, Green House Gases, and Energy for future and Emissions are matter of concern not only for developed countries but also for the developing as well as the underdeveloped countries. India being the largest and rapidly growing developing country the issue of energy intensity needs special focus. However, the discussion on the energy intensity should not be at the aggregate level/ at national level. Specific interest must be given for the sub sectors as well. This work is an attempt in understanding the factors those determines the changing energy intensity pattern in Indian manufacturing using a panel data from 2000.2008. In addition, Energy intensity in Indian Manufacturing firms 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 of Energy Intensity behaviour of Indian Manufacturing firms.

The major findings of the study are as follows:

- We found that technology imports activities of firms are one of the important contributors in declining the firm-level energy intensity and hence increasing the energy efficiency of the firms.

- The analysis has brought that foreign ownership is important determinant of energy intensity of Indian manufacturing. Results confirm that foreign ownership lead to higher efficiency.
- A positive relation is found between R&D and energy intensity.
- We found a negative relationship between energy intensity and firm size
- A positive relation is established between the age of the firm and the energy intensity
- We found the capital intensive as well as the labour intensive firms are more energy intensives.

References

Andersen, F.M. Andersen, D. Celov, D. Grinderslev and E. Vilkas, (1998), A Macro-Econometric Model for Lithuania LITMOD, LMA Ekonomikos Institutas, Lithuania

Ang, B, W, (2004), Decomposition analysis for policymaking in energy: which is the preferred method?, Energy Policy 32, pp. 1131–1139.

Ang, B. W., (1995a), Decomposition methodology in industrial energy demand analysis, Energy 20, pp. 1081–1095

Ang, B. W., (1995b), Multilevel decomposition of industrial energy consumption, Energy Economics 17, pp. 39–51.

Berndt, E.R. and Wood, D.O., (1975), Technology, Prices, and the derived demand for energy. Review of Economics and Statistics, 57 3, pp. 259–268

Centre for Monitoring Indian Economy (CMIE), (2007), “Energy”

Greening, L. A. William B. D & Lee S, (1998) Decomposition of aggregate carbon intensity for the manufacturing sector: comparison of declining trends from 10 OECD countries for the period 1971–1991, Energy Economics, 20 (1), pp 43-65

Griffin J. M. and Gregory P.R., (1977), An inter-country translog model of energy substitution responses, American Economic Review 66, pp. 845–858

Grover R. B., and Subash C., (2004), “A strategy for growth of electrical energy in India”, Document No 10, Department of Atomic Energy, Mumbai, India

Halvorsen, R, (1977), Energy substitution in US manufacturing, Review of Economics and Statistics 59 4, pp. 381–388.

International Energy Agency (IEA), (2007) ‘World Energy Outlook 2007 Highlights’

International Energy Agency (IEA), (2007), Key World Energy Statistics, 2007.

Joyce M., Dargay, J, M (1983), The Demand for Energy in Swedish Manufacturing Industries, The Scandinavian Journal of Economics, Vol. 85, No. 1, pp. 37-51

Kleijweg, A., Leeuwen, G. Van, Huigen, R., Zeelenberg, K., (1989). The demand for energy in Dutch manufacturing; a study using panel data of individual firms, 1978–1986. Research Paper 8906, Research Institute for Small and Medium-sized Business in the Netherlands, Department of Fundamental Research.

Kumar N., (1987)`Technology Imports and Local R&D in Indian Manufacturing, Developing Economics,25(3),220-33.

Kumar, N. and M. Saqib (1996) "Firm Size, Opportunities for Adaptation, and In-House R&D Activity in Developing Countries: The Case of Indian Manufacturing." Research Policy, 25, pp. 712-722

Lorna A. G., William B. D., Schipper L, and Marta K., (1997) Comparison of six decomposition methods: application to aggregate energy intensity for manufacturing in 10 OECD countries, Energy Economics, Volume 19, Issue 3, July, Pages 375-390

Mitra A., Varoudakis A. and Veganzones M., (1998), State infrastructure and productive performance in Indian manufacturing, Technical Paper, OECD Development Centre, Paris

Narayanan K, Banerjee S, (2006): “R & D and Productivity in Select Indian Industries”, ICFAI Journal of Industrial Economics, Vol.3, No.2, pp 9-17.

Papadogonas T, Mylonakis J, Demosthenes Georgopoulos (2007), Energy consumption and firm characteristics in the Hellenic manufacturing sector, International Journal of Energy Technology and Policy, Vol 5: 1, pp 89-96

Pindyck, R, S, (1979), Interfuel substitution and the industrial demand for energy: an international comparison. Rev. Econ. Stat. 61 2, pp. 169–179

Prowess Data base, CMIE, (September 12, 2008)

Puran M and Jayant, (1998), “Productivity Trends in India's Energy Intensive Industries: A Growth Accounting Analysis”, Ernest Orlando Lawrence Berkeley National Laboratory, LBNL-41838

Rodrik D and Arvind S, (2004), “Why India can grow at 7 percent or more: projections and reflections”, IMF Working Paper, WP/04/118.

Saumitra B and Rajeev. K. C. (2000), “Decomposition of India’s Industrial Energy Use: A Case Study Using Energy Intensity Approach”, International Journal of Global Energy Issue, Vol. 17, No. 2, pp. 92-105

Siddharthan N.S., and Agarwal R. N., (1992), Determinants of R&D Decisions: A Cross-Section Study of Indian Private Corporate Firms, Economics of Innovation and New Technology, Vol 2:2, pp 103-110

Subrahmanya B. M. H. (2006), Labour productivity, energy intensity and economic performance in small enterprises : A study of brick enterprises cluster in India, Energy conversion and management, vol. 47, no 6, pp. 763-777

Thomsen, T, (2000), Short cuts to dynamic factor demand modeling, Journal of Econometrics 97, pp. 1–23

Vanden K.F., Jeferson G.H., Hangmei L., Quan T.(2002), `What is Driving China's Decline in Energy Intensity', weber.ucsd.edu/~carsonvs/papers/787.pdf

Woodland, A.D. (1993): A Micro-econometric Analysis of the Industrial Demand for Energy in NSW. Energy Journal, 14(2): 57-89.