Determinants of Energy Intensity: A Preliminary Investigation of Indian Manufacturing

Sahu, Santosh and Narayanan, K

Indian Institute of Technology Bombay

16 April 2009

Determinants of Energy Intensity:
A Preliminary Investigation of Indian Manufacturing

Santosh Kumar Sahu* & K. Narayanan$^{\Phi}$

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. In this context the energy intensity is one of the key factors which impact the projections of future energy demand. The Indian manufacturing sector is among the largest consumer of commercial energy compared to the other industries in India. Energy consumption per unit of production in the manufacturing of steel, aluminum, cement, paper, textile, etc. is much higher in India, in comparison to other developing countries. The purpose of this study is to understand the factors that influence industrial energy intensity in Indian manufacturing. The analysis undertaken in this paper find a positive relationship between energy intensity and firm size and an inverted U' shaped relationship between energy intensity and size of the firm. The analysis shows that the foreign owned firms are less energy intensive compared to the domestic firms. Capital intensive firms as well as firms spending more on repair and maintenance are found to be more energy intensive. Further the results shows that expenditure on the research and development contribute to reduce firm level energy intensity and there is a sizable difference between highly energy intensive firm and less energy intensive firms.

JEL Codes: Q4, B23

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

* Research Scholar, Department of Humanities & Social Sciences, Indian Institute of Technology Bombay, Mumbai, India, santoshks@iitb.ac.in

$^{\Phi}$ Professor of Economics, Department of Humanities & Social Sciences, Indian Institute of Technology Bombay, Mumbai, India, knn@iitb.ac.in

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 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. 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 by 26%; the Group of Seven's (G-7[3]) fell by 29%; and the U.S.' dropped by 34% (IEA, 2007[4]).

A 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

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

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] 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 (GoI, 2007). 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 have been conducted in Total Factor Productivity (TFP) and Technical Efficiency in Indian Manufacturing (Mitra et al; 1998; Golder, 2004) in India. Studies have also reported 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 Banarjee, 2006; Kumar and Saqib; 1996, Siddharthan and Agarwal 1992). Demand for energy in Indian manufacturing industries at aggregate level as well as for specific industries, is also of much

[6] ibid
[7] Organization of Economic Co-operation and Development
[8] planningcommission.nic.in/plans/planrel/fiveyr/welcome.html

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 of the determinants of energy intensity of Indian Manufacturing. This study attempts to examine the relationship between firm level energy intensity and 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 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 that 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 very few studies which indicate the energy intensity for specific industries. In this context, a 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, very large number of studies dealing with 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 of 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 for 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 factors of production. 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 on the basis of simply extrapolating the historical sectoral production growth trends.

3. Data sources, Methodology and Hypotheses

The present study analyzes the determinants of energy intensity of Indian manufacturing sector. The analysis is carried out using data for a sample of industrial firms. Multiple regression equation is estimated from cross section data for analyzing the determinants of Energy intensity. The data for the analysis has been drawn from the online Prowess Data Base (as on September, 2008) of the CMIE. The potential data set encompasses a large unbalanced panel consisting of 10,126 observations for the year 2008. Of these many are missing, which leaves a total of 2,350 observations for the analysis.

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 paid for using their trade marks, brand name etc. While these innovation activities lead to product or process innovation, they may also have measurable effect on energy intensity. Considering age of the firm as an indicator can be justified with an assumption that the firms having long experience in production are likely to incur relatively more expenditure on R&D compared to younger firms and hence the energy intensity of the older firms may very significantly compared to the younger firms. Different industries use different technologies that exhibit different levels of energy intensity. To compare the medium energy intensive firms with the higher and the lower energy intensive firms, we have constructed a dummy variable (industry dummy), where the sample dataset is divided in two groups based on the energy intensity (the higher energy intensive firms are defined as the firms whose energy intensity is more than the mean energy intensity of the sample or else defined as the less energy intensives). 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:

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

Where:

*energy*int: Energy Intensity, *capital*int: Capital Intensity, *rd*int: Research Intensity, *tech*int: Technology Import Intensity, expint: Export 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, *industrydummy*: A dummy used for the firm if it's foreign owned, and *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	Labour intensity as a ratio of the wages and salaries to the sales	-ve
3	Capital Intensity	The ratio of the total capital employed to the total value of the output	+ve
4	Technology Import intensity	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	The ratio of R&D expenses to the sales.	+ve / -ve
6	Profit Margin	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	Export Intensity	This variable is measured as the ratio of export to the sales	+ve / -ve
9	Size	Size of the firm is measured by the sales. Here we have taken the natural log of the sales to define size of the firm	+ve
10	Age	As a measure of age, we subtract the year of incorporation from the year of the study.	+ve
11	Industry Dummy	This dummy takes the value 0, if the firm is less energy intensive and one for the rest	+ve
12	Firm Dummy	This dummy takes the value one for the foreign owned firms and zero for the rest	-ve

Hypotheses: 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
- Older firms may find it difficult to change their style of operation and hence could be more energy intensives

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. We have tried to analyze nine different industries for our purpose. Table 4.1 shows the key ratios of different indicators of Indian manufacturing sector at aggregate level. All the results given in table are for a period of one year i.e. 2007.

Table 4.1: Key ratios of different indicators in percentage

Description	Energy Intensity	labour intensity	Capital Intensity	Technology import Intensity	export intensity	R&D intensity	Profit Margin
Chemicals	2.10	2.50	34.72	1.10	16.17	0.47	7.09
Diversified	5.34	7.28	46.64	1.63	8.18	0.12	8.51
Food & beverages	2.52	5.08	31.34	1.17	12.97	0.15	8.29
Machinery	1.23	7.01	25.53	1.43	9.23	0.72	11.29
Metals & metal products	7.24	5.26	62.83	1.67	22.61	0.08	18.80
Miscellaneous manufacturing	7.37	10.22	63.01	3.30	9.56	0.12	10.85
Non-metallic mineral products	13.24	4.67	60.16	1.90	24.43	0.06	16.98
Textiles	7.62	6.59	75.29	6.24	26.64	0.09	6.45
Transport equipment	1.56	5.96	30.63	3.46	10.27	1.43	10.70
Overall	5.35778	6.06333	47.7944	2.4333333	15.5622	0.36	5.35778

Source: Own estimates from Prowess Data Base, 2007

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.

From table 4.1 it is clear that 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.

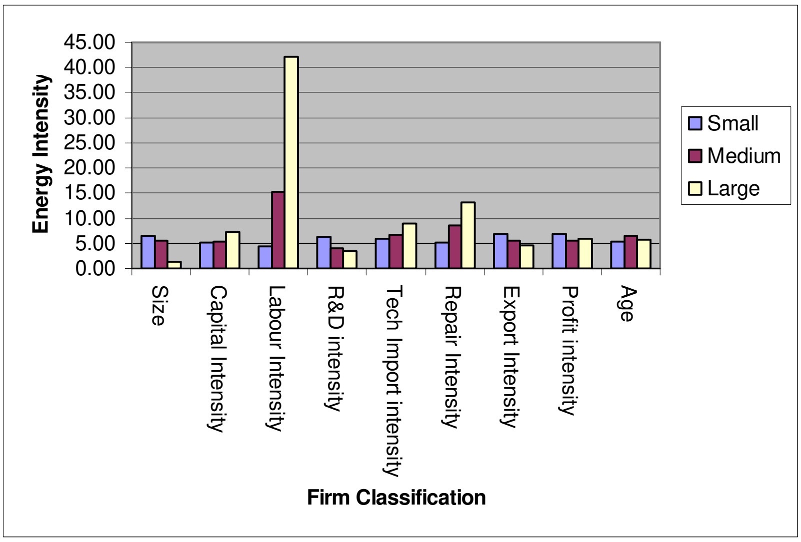
The above discussion tries to find out the major key ratios to understand the Indian manufacturing sector at aggregate level as well as to observe the most energy intensive ones. However as the study is focused on determining the factor effecting energy intensity at firm level using firm level data for 2007, the firm level characteristics of the data need to be well described . Therefore the next section deals with the classification if the industries (2,350 observations) 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 4.2 is not based on industry type; rather we have classified the entire manufacturing data based on the earlier classification for different indicators. The result is given in table 4.2 and presented in figure 4.1.

Table 4.2 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
Export Intensity	6.92	5.52	4.59
Profit intensity	6.87	5.44	5.83
Age	5.40	6.58	5.67

Source: Own estimates from Prowess Data Base, 2007

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



From table 4.2 and figure 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. And 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 2,350 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. Export and profit 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 export/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.

5. Empirical Findings

Table 5.1 presents the descriptive statistics of the sample of 2,350 firms. The mean energy intensity of the sample is calculated to be 0.06. The minimum energy intensity of the sample stands at zero where as the maximum energy intensity is of 0.68. The labour intensity has a mean of 0.06, and the maximum labour intensity calculated to be 1.86. Capital intensity of the sample firms has a mean of 0.45, where the minimum capital intensity is calculated to be 0.02 and the maximum is calculated to be 1.00. The mean repair intensity if the sample is calculated to be 0.01 and the highest repair intensity is calculated to be at 0.27. The research intensity has a mean of 0.01, where as the maximum research intensity is calculated to be 6.15. Which means there are firms which are spending less amount on the R&D activities as well there are firms which are spending higher amount in research and development activities.

Table 5.1 Descriptive Statistics of the Sample

Variable	Mean	Std. Dev.	Min	Max
Energy Intensity	0.06	0.07	0.0004	0.68
Labour Intensity	0.06	0.07	0.004	1.86
Capital Intensity	0.45	0.22	0.02	1.00
Repair Intensity	0.01	0.02	0.00	0.27
Research Intensity	0.01	0.13	0.00	6.15
Technology Import Intensity	0.02	0.07	0.00	0.95
Export Intensity	0.17	0.28	0.00	4.76
Profit Margin	0.06	0.14	-3.33	0.75
Size of the Firm	4.63	1.71	0.05	12.31
Age of the Firm	29.42	20.56	1.00	182.00

No of observations: 2,350

The mean technology import intensity lies at 0.02 with a maximum value of 0.95. The potential data set consists of a combination of nine different industries and hence the export intensity is too widely distributed. The mean export intensity is calculated to be 0.17 whereas the highest export intensity is calculated to be 4.76. In the same way being 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 0.06, however the lowest profit margin is calculated to be -3.33 and the highest being 0.75. Mean firm size is calculated to be 4.63, with the lowest firm size at 0.05 and the largest firm size of 12.31. The mean age of the potential data set is calculated to be 29.42, where the minimum age of the firm is as young as one year and the maximum age is as old as 182 years. The percentile distribution of the sample is 5.2.

Table 5.2 Percentile distribution of the sample

Percentiles	Energy Intensity	Labour Intensity	Capital Intensity	Repair Intensity	Research Intensity	Tech import Intensity	Export Intensity	Profit Margin	Size	Age
1%	0.0004	0.002	0.045	0.0004	0.000	0.000	0.000	-0.302	0.742	4
5%	0.003	0.007	0.119	0.001	0.000	0.000	0.000	-0.070	1.918	9
10%	0.005	0.011	0.163	0.002	0.000	0.000	0.000	-0.013	2.523	12
25%	0.013	0.025	0.271	0.004	0.000	0.000	0.000	0.016	3.448	16
50%	0.035	0.050	0.421	0.009	0.000	0.001	0.036	0.048	4.593	22
75%	0.082	0.081	0.612	0.017	0.001	0.014	0.216	0.104	5.758	37
90%	0.145	0.132	0.760	0.031	0.006	0.056	0.560	0.168	6.797	59
95%	0.202	0.176	0.842	0.041	0.015	0.103	0.785	0.223	7.447	72
99%	0.342	0.327	0.958	0.071	0.071	0.285	0.942	0.353	9.066	102

No of observations: 2,350

Table 5.3 presents the correlation coefficient between the variables used in the model. From the table it can be seen that the correlation coefficients However in few cases the correlation coefficients are reported very less. The correlation coefficient between energy intensity and labour intensity, capital intensity, repair intensity, technology intensity, industry dummy and age are turned out to be positive. That means there is a unidirectional relationship between the energy intensity and the other variables. Where as the correlation coefficient between the energy intensity and research intensity, export intensity, profit margin, size and firm 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 5.4 below.

Table 5.3 Correlation Result

	energy~y	labour~y	capita~y	repair~y	rdinte~y	techin~y	export~y	profit~n	size	size2	indust~y	firmdu~y	age
energyinte~y	1.00												
labourinte~y	0.15	1.00											
capitalint~y	0.14	0.13	1.00										
repairinte~y	0.30	0.35	0.14	1.00									
rdintensity	-0.02	0.00	-0.03	-0.01	1.00								
techintens~y	0.08	0.19	0.15	0.05	0.00	1.00							
exportinte~y	-0.08	-0.04	0.10	-0.04	0.00	0.20	1.00						
profitmargin	-0.08	-0.31	0.11	-0.09	0.01	-0.09	0.01	1.00					
size	-0.11	-0.28	0.01	-0.21	0.01	0.03	0.05	0.21	1.00				
size2	-0.10	-0.23	0.01	-0.17	0.00	0.03	0.04	0.19	0.97	1.00			
industrydu~y	0.60	0.14	0.04	0.14	-0.01	0.05	-0.06	-0.10	-0.07	-0.05	1.00		
firmdummy	-0.09	0.06	0.02	-0.01	0.00	0.02	0.01	0.08	0.11	0.11	-0.03	1.00	
age	0.05	0.24	-0.02	0.17	-0.01	-0.04	-0.13	0.05	0.17	0.18	0.01	0.07	1.00

This discussion is pertaining to the estimation of the regression equation. We have estimated regressions equation for the period 2007 using cross-sectional data (see Table 5.4).Table 5.4 summarizes the findings of the estimation. We have used STATA 8.2 for estimating the results. Although R-square is rather low at 18 percent, it is reasonable given the large heterogeneous cross section of companies covered in the sample. The F statistics has 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

Explanatory Variables	Coefficient	t value
Labour Intensity	-0.200	-0.46
Capital Intensity	0.917	7.85***
Repair Intensity	18.163	11.05***
Research Intensity	-0.092	-0.47
Technology Import Intensity	0.799	2.02***
Export Intensity	-0.168	-1.79**
Profit Margin	-0.328	-1.69**
Size	0.192	3.29***
$Size^2$	-0.026	-4.69***
Industry Dummy	2.062	11.06***
Firm Dummy	-0.485	-4.30***
Age	0.003	2.80***
Constant	-4.476	-28.06
Number of observations	2350	
F (12, 2337)	43.96***	
R-squared	0.184	
Adj R-squared	0.180	

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

The coefficient of the firm size is found to be significant and positive and the coefficient of the size square fond to be significant and negative. Thus indicate that that the energy intensity is higher in case of the firms which are bigger in size, as we hypothesized and lower for the smaller firms. Hence there is an inverted U' shaped relationship exists between the energy intensity and the size of the firm.

For repair intensity variable the coefficients is 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. Hence the repair intensity has turned out to be one of the major determinants of the energy intensity at firm level.

A negative relationship is found between profit-margin, export intensity and energy intensity which imply that profitability of firm and export intensity seems to be negatively affecting the intensity on energy. Or in other word it can be said that the profitable firms as well the export oriented firms are adopting energy savings technology and hence the intensity of energy is comparatively less than that of the less profitable firms.

Capital intensity is found to be important determinants of energy intensity (positive and significant). That means that more capital intensive firms are more energy intensive. Papadogonas et al (2007), found similar result for Hellenic manufacturing sector.

R&D intensity turned out to be negative coefficient but this variable is not significant. Hence the R&D intensity does not seem to be affecting the energy intensity; this might be the fact that many firms don't report their spending on R&D (Table 5.1, 5.2). However the negative sign on the coefficient implies an increase in R&D activities increase energy efficiency and hence decrease the energy intensity.

It is interesting to note that the technological import intensity variable is turned out to be one of the determinants of energy intensity and it bears positive relationship, as technology imports are followed by further technological effort for absorption of imported knowledge which requires more energy.

The firm 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 and highly significant. 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 industry dummy has turned out to be positive and highly statistically significant. That means that the energy intensity are more for the energy intensive industries compared to the less energy intensive industries.

6. Summary and Conclusion

In this paper a preliminary investigation of Energy Intensity of Indian Manufacturing firms has been carried out. The increasing 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 that 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 R&D activities are important contributors to the decline in firm-level energy intensity.
- 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 technology import and energy intensity.
- We found a positive relationship between energy intensity and firm size
- We found that different industries use technologies that exhibit different levels of energy intensity.
- We found age has a positive relationship with the energy intensity of the firm.

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.