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DETERMINANTS OF ENERGY AND CO2 EMISSION INTENSITIES: A STUDY OF MANUFACTURING FIRMS IN INDIA

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Abstract

This paper investigates the determinants of energy and emission intensities of manufacturing firms in India, from 2000 to 2014. Given that Indian manufacturing sector is one of the world's most polluting sectors in terms of CO2 emissions; we arrive at firm level determinants of energy and carbon dioxide emission intensities from consumption of three primary sources of energy, namely (1) Coal, (2) Natural Gas and (3) Petroleum. Based on the methodological argument by Barrows and Olliviery (2014), we employ two different definitions in calculating energy intensity and relate with firm characteristics. Data for this study is collected from Prowess 4.0. The results of the regression analysis suggest that there are inter-firm differences in energy and emission intensity. Given that the emission coefficients are derived from the bottom-up approach, firms that are energy intensives are also found to be emission intensives. The results of the study indicate that smaller and larger firms are both energy and emission intensives compared to the medium sized firms. Similarly, firms spending more in research and development activities are found to be energy and emission efficient compare to others. Hence, in the global competitive business environment, Government of India should carefully formulate policies suitable for the medium sized firms to make them energy and emission efficient.

Keywords: *Energy Consumption, CO2 Emission, Indian Manufacturing Industries*
JEL Codes: *Q4, B23*

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INTRODUCTION

Energy has been one of the most important factors for economic growth and human development. An economy's growth along with its global competitiveness depends on the availability of cost-effective and environmentally benign energy sources. It also depends on the level of economic development has been observed to be reliant on the energy demand. Energy is indeed one of the major drivers of a growing economy like India and is an essential building block of economic development. In order to meet the demands of a developing nation, Indian energy sector has witnessed a rapid growth. There has been a revolution in areas like resource exploration and exploitation and capacity additions. India being the fourth largest consumer of energy in the world after USA, China and Russia, is still not endowed with abundant energy resources. Thus, it has to meet its development needs by using available domestic resources of uranium, coal, hydro, oil and other renewable resources and supplementing the domestic by imports.

All the actions to address climate change finally involve costs. Funding of energy is vital for developing countries like India in order to design and implement the adaptation and mitigation plans and projects. The problem becomes more severe for India, which in future would be one of the hardest hit countries by climate change, given its need to finance developmental issues like poverty eradication, food security, providing clean drinking water and sanitation etc. India is expected to grow at such a rapid rate over the next two decades and growth of this magnitude will bring tremendous benefits to the country, but it also poses many challenges, particularly regarding sustainability. Demand for resources will increase dramatically, raising its dependence on imports for commodities such as crude oil and driving commodity prices higher in general. Also, it will need to expand its capacity to generate electricity to meet increasing industrial and residential demand, which will impel a corresponding increase in greenhouse-gas (GHGs) emissions.

A strong correlation has been found to exist between energy consumption and economic growth. Excessive energy use results in increasing GHGs emissions. Various estimates indicate that approximately 50-60 percent of all Carbon Dioxide (CO_2) emissions come from manufacturing sector in most of the developing countries. Thus, it is implied that economic growth depends on energy usage which in turn leads to environmental degradation. However, it has been argued that economic growth may bring an initial phase of deterioration but later on, due to the adoption of better abatement technologies, it might bring some improvement to the quality of the environment. India faces many challenges in terms of its energy use and increasing emissions of CO_2 when tasked with meeting domestic energy demand and reducing GHGs emissions. It has been observed that Coal consumption is the largest source of energy in India followed by oil and natural gas. India's fast growing economy requires action to substantially increase energy capacity. The challenge here is to meet the energy needs of achieving 8 percent to 9 percent economic growth while also meeting energy requirements of the population at affordable price. In order to meet such high demands, India's reliance on energy imports has been increasing substantially posing further challenges in this aspect. High reliance on imported energy is costly given the prevailing energy prices. It calls for a sustained effort at increasing energy efficiency to contain the growth in demand for energy while increasing domestic production as much as possible to keep import dependence at a reasonable level. Currently, 75 percent oil is imported, which is estimated to rise to 80 percent, import of gas is listed at 19 percent, marked to grow to 28 percent and coal import is forecasted to rise from the current level of 90 million tons to more than 200 million ton over the next two decades. Further deepening the impact of such energy issues, another major negative externality that has been imposed by high use of energy resources like oil, fossils and other fuels is emissions of GHGs such as CO2, Methane etc.

Despite its increasing engagement on climate issues, India has not wavered from its position that equity concerns must underlie the international climate negotiations. It has been argued that developing countries like India must be supported financially, technologically, and with capacity-building resources by developed economies so that they can cope with the immense challenges of adaptation. Many attempts have been made to reduce such emissions in terms efficient utilization of energy sources. Thus, came into effect the Clean Development Mechanism (CDM) with the purpose to help developing countries achieve sustainable development and to assist industrialized countries in complying with their emission reduction commitments. It is a project-based mechanism, whereby eligible entities from developed countries are expected to finance emission reduction projects in developing countries and use carbon credits generated by these projects to meet a portion of their GHGs reduction commitments under the protocol. The basic principle of the CDM is developed countries can invest in developing countries and receive credit for the resulting emissions reductions at low costs while developing countries benefit from the increased clean investment and technology flows. India is second only to China, in using this mechanism to help reduce its carbon emissions. CDM allows industrialized countries that have, as Kyoto parties, committed to reducing their national carbon emissions to instead support climate mitigation projects in developing countries, such as renovating power plants or installing solar panels. Since the cost of carbon abatement is often lower in developing than in industrialized countries, the CDM allows industrialized countries to cost-effectively reduce their greenhouse gas emissions while promoting sustainable development in countries that host CDM projects.

The goal is to combine technical assistance in the design and implementation of investment projects, advice on policy and institutional reforms and direct links with investment funds in order to facilitate compliance with future legally binding reduction targets for GHGs. Thus, many attempts have been made to reduce such emissions in terms efficient utilization of energy sources. Indian Manufacturing sector has been one of the major sectors contributing to high carbon emissions in the country. Very few studies in this context have been carried out to access the relationship between firm level emission intensity and energy intensity based on firm characteristics; differentiating energy intensity in terms of energy consumption in physical units. Similar studies in this field mainly use the economic definition of energy intensity in terms of its consumption. This study looks into Indian manufacturing sector while looking into firm level energy intensity and CO_2 emissions. There exist many definitions of energy intensity; however, the focus here has been on the "thermodynamic-economic" definition of energy intensity which is the consumption of energy in physical units calculated in British Thermal units (BTU) as a ratio of production in economic units. Further, this paper looks into the estimation of CO_2 emission coefficient for firms based on their choice of energy source, along with examining the firm level determinants of both energy and emission intensity.

REVIEW OF LITERATURE

According to the Planning Commission of India, energy intensity is defined as the energy input associated with a unit of gross domestic product (GDP) which is a measure of the energy efficiency of any economy, i.e., how efficiently energy is used in the economy. However, it has been observed that for India, it has been declining over the years and is expected to decline further.

The paper by Murthi and Parikh (1997) investigates the linkages between economic growth, energy consumption and carbon dioxide (CO_2) emissions in India by analyzing the structure of production and consumption in the Indian economy. According to their study, CO_2 emissions are projected to increase from 0.18 tonnes of carbon (tC) per capita in 1990 to about 0.62 tC per capita in 2020 under the reference scenario which corresponds to a GDP growth rate of 5.5 percent per annum. India's 2008 total fossil-fuel CO_2 emissions rose 8.1 percent over the 2007 level to 475 million metric tons of carbon. From 1950 to 2008, India experienced dramatic growth in fossil-fuel CO_2 emissions averaging 5.7 percent per year and becoming the world's third largest fossil-fuel CO_2-emitting country. Indian total emissions from fossil-fuel consumption and cement production have more than doubled since 1994. Fossil-fuel emissions in India continue to result largely from coal burning with India being the world's third largest producer of coal. Coal contributed 87 percent of the emissions in 1950 and 71 percent in 2008; at the same time, the oil fraction increased from 11 percent to 20 percent. With the world's second largest population and over 1.1 billion people, India's per capita emission rate for 2008 of 0.40 metric tons of carbon is well below the global average of 1.30 and the smallest per capita rate of any country with fossil-fuel CO_2 emissions exceeding 50 million metric tons of carbon.

Aggarwal (2015) argues that achieving the global reduction of GHGs requires innovation to transform current technologies into cleaner and climate resilient technologies. But radical innovations are largely concentrated in a few highly industrialized countries. Developing countries which are at a greater risk of climate change impacts have low technological capability to shift to low carbon and climate resilient growth paths. They must either develop the technology by their own means or purchase it from developed countries both of which are costly options. However, there is evidence that the CDM established in 1997 by the Kyoto Protocol (KP), is the largest market based mechanism that incentivizes the private sector to finance low-carbon technology transfer to developing countries (Schneider et al., 2008). She further defines such technological capability in two ways: narrow and wider. According to her, the narrow approach focuses on the domestic R&D efforts and the wider definition focuses on dynamic capabilities of firms which influence their performance. It implies that technology imports (via CDM) may substitute internal R&D efforts and hence adversely affect the technological capabilities of local firms. She thus hypothesized that the CDM implementation affects local R&D efforts positively. The high transaction cost of implementing CDM projects thus may however affect the firms' financial capacity to invest in local R&D and the hypothesis may turn out to be weakly established. From the perspective of CDM projects, energy efficiency may be an important indicator of performance. This is because energy related projects dominate the portfolio of CDM projects worldwide. Technologically and dynamically capable firm is likely to export more. Further, the implementing firms are expected to generate substantial goodwill in international markets by adopting cleaner technologies and may be able to export more. However, the CDM implementation costs may affect their cost competitiveness and hence the export performance. The impact of CDM implementation on exports may thus turn out to be weak. She also points out that since 2007 however, there has been a continuous decline in the yearly number of such projects due to global slowdown and fall in the international prices of certified emission reductions. These patterns further indicate that the role of CDM as a means of upgrading technological capabilities of firms is expected to be limited. The existing studies also bring out the limitations of CDM in supporting large scale technology transfers.

Furthermore, a study by Sahu (2014) has tried to find the relationship between the profitability and energy intensity of Indian manufacturing industries. Energy intensity is found to be positively related to profitability. The results suggested that firms adopting petroleum and coal as the primary energy sources are both energy intensive and profitable, indicating that with increase in capital and energy intensity, profitability of firms increases. It implies that firms that are capital and energy intensive are profitable. The findings do indicate variable role of energy as well as other firm specific characteristics in determining profitability. It also suggests that for the Indian manufacturing sector, firms using natural gas are becoming energy efficient as well as profitable. Hence, shifting from coal or petroleum to natural gas as the primary energy source, firms can become energy efficient and profitable. In addition, using natural gas there is a possibility of reducing CO2 emissions from the fuel use. In the debate of CDM and issues in climate change, shifting from traditional fuel sources to recent fuel source might help in reducing CO2 emissions specifically for developing country such as India. Higher research and development and technological advancement in production process as well as for product development will also help Indian manufacturing firms in achieving higher profitability and energy efficiency.

Barrows and Olliviery (2014) investigates the impact of exporting on the CO2 emission intensity of manufacturing firms in India. They found that that prices systematically bias estimates when emission intensity is measured in value; that firms adjust emission intensity in quantity through changing output shares across products, but that firms do not lower emission intensity within products over time (technology).

The results imply that the productivity benefits from market integration alone are not enough to induce clean technology adoption. Their research has found that exporters have lower emission intensity than non-exporters, which is consistent with a technology upgrading model in which firms adopt more-efficient, cleaner technology when they start exporting. Then they asserted that that firm-level emission intensity in quantity falls 0.38 percent with an (instrumented) 1 percent increase in export value.

The study by Narayanan and Sahu (2013) indicates that there exist significant differences in firm level emission intensity which is related to identifiable firm specific characteristics. This study found size, age, energy intensity and technology intensity as the major determinants of CO2 emission intensity of Indian manufacturing firms. In addition capital and labour intensity of the firms are also related to the firms' emission intensity. It suggests that firms with the larger capital are emitting less compared to firms with the smaller capital. Also, that older and bigger firms are emitting less and here capital intensive firms are also emitting less. Hence, it has been assumed that older and bigger firms might be higher capital intensive firms. Indian manufacturing industries play a significant role in the country's economic growth. However, in global competitiveness in this sector has to upgrade the technologies and should achieve energy as well as emission efficiency. In addition, specific policy measures should be formulated to encourage medium sized and older firms to upgrade technology and invest in technology import and research & development pertaining to eco-innovation to reduce CO2 emission. In addition reducing fossil fuel consumption and adopting cleaner and green energy firms will be able to become both energy and emission efficient. The contribution of this paper lies in estimating CO2 emission at the firm level and analyzing the factors that explain inter-firm variation in CO2 emission. It suggests that the short run policy implications should be aimed at encouraging firms to invest more in R&D and technology sourcing and at long run firm should be able to adapt cleaner energy to reduce CO2 emission from the fuel consumption. R&D, technology sourcing, fuel switching, should be given due attention for green growth of India. Finally, it concludes that energy intensive firms are also emission intensive.

DATA, METHODOLOGY AND DESCRIPTIVE STATISTICS

Data are collected from the Center for Monitoring Indian Economy (CMIE) Prowess database. The period of the study is from March, 2000 to March, 2014 (15 years). The data for the manufacturing industries at firm level at annual in frequency those derived from the annual balance sheets of the firms from the Prowess database. After a thorough cleaning of data, we have arrived at 5421 number of firm-year observations. The data used in the analysis is an unbalanced panel data. The data collection process was done in two steps. First set has the data which has been collected from the annual financial statements and the second set of data comprises of the energy consumption data of these manufacturing firms from the business segment query in the prowess database that include (1) Coal, (2) Natural Gas and (3) Petroleum. Most firms have reported the consumption of coal and natural gas as their primary source of energy. However, very few have reported data for Petroleum as the primary source of energy consumption. However, we have still considered this segment as it will later account for the calculation of energy intensity. Electricity consumption is reported by nearly all the firms. However, we have not taken electricity as a primary source to avoid the problem of 'double counting' as the source of electricity generation has not been specified. From both the sources of data, matching of firm-data was arrived for each of the firms for the energy use and firm characteristics.

An Empirical Model of Energy Intensity

To incorporate the firm characteristics to an empirical model of energy and emission intensity, we follow Doms & Dunne (1995) based on energy factor demand equation from a cost minimization model. Suppose each firm's short-run variable cost function has the following form:

$$VC(\tilde{p}, y, K, \tilde{z}, t) = y.AVC(\tilde{p}, K, \tilde{z}, t), \tag{1}$$

Where "*VC*" is a variable cost function, "*p*" is a vector of input prices, "*y*" is output, "*z*" is a vector of plant characteristics expected to affect costs, "K" represents the fixed factor capital, "*t*" incorporates measures of firm's technology, and "*AVC*" is an average variable cost function. The above expression equates total variable cost to output times, average variable cost and implies a, constant returns to scale technology. Differentiating (1.1) with respect to the i^{th} input price p_i and applying Sheppard's lemma yields,

$$\frac{\delta C}{\delta p_i} = y.\frac{\delta AVC}{\delta p_i}(\tilde{p}, K, \tilde{z}, t) = x_i^*. \tag{2}$$

Where "x_i^*" is the cost-minimizing quantity of the i^{th} factor. This is the standard expression for the i^{th} factor demand equation in a unit variable cost framework. In this paper, we follow the approach as followed by Dom & Dunne (1995), and focus on the factor demand equation for energy consumption and re-express it in intensity form as,

$$\frac{x_E^*}{y} = \frac{\delta AVC}{\delta p_E}(\tilde{p}, k, \tilde{z}, t). \tag{3}$$

Equation (3) express that energy consumption per unit of output is a function of input prices, the capital stock, plant characteristics, and technology. To estimate (3) we must first specify a functional form for the AVC function. We will utilize a double-logarithmic form for the empirical analysis, as follows:

$$\ln\left(\frac{x_E^*}{y}\right) = \sum_{i=1}^{j} \beta_i \ln p_i + \sum_{i=1}^{k} \theta_k \ln k + \sum_{i=1}^{k} \alpha_i z_i + \sum_{i=1}^{m} \gamma_i t_i \qquad (4)$$

The dependent variable in equation (4) is energy intensity at firm level. There are many definitions of energy intensity. However, for the purpose of this study, the "thermodynamic definition of energy intensity" (EI) is used defined as energy consumption in physical units measured in British Thermal Units (BTU), divided by net sales of the firm.

The first set of independent variables represent factor prices at the firm level. This vector includes the firm-level labour input. The next set of the independent variable presents a firm specific measure of the fixed factor capital. One of the reason for the specification is it controls the variation in energy intensity different firm size. The vector *"z"* contains a set of production process variables. Other control variables include age of the firm. As an improvement to Dom & Dunne (1995), we have added the firm size. Firm size is considered to capture the inter-firm difference in energy intensity. 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 firms. The technology imports are likely to affect the energy intensity. Whether these innovation activities lead to product or process innovation, they may have measurable effect on energy intensity. In case of the Indian manufacturing industries, at secondary level it is difficult to get the vectors of the technology implemented. Hence, we have classified the technology sourcing as two components. The first component takes care of the expenses on R&D intervention and the second is the technology imports by firms.

Computation of CO_2 Emission Coefficients

Due to lack of firm level data on CO2 emissions, emission coefficient has been calculated using information obtained from the annual balance sheet of the firms and their energy consumption reports from the prowess database. Using IPCC reference approach of estimating coefficient of emission for a given source of energy and its physical consumption in BTU by a firm, CO2 emissions coefficients are calculated. The Reference Approach methodology breaks the calculation of carbon dioxide emissions from a given source of energy consumption into 5 steps such as 1. Estimate apparent fuel consumption in original units, 2. Convert to a common energy unit, 3. Multiply by carbon content to compute the total carbon, 4. Compute the excluded carbon, and 5. Correct for carbon unoxidised and convert to CO2 emissions. The formulae of calculating the emission coefficient is as follows.

$$CO_2 = \sum_{i=n} \left[\left(\left(ac_f \times cf_f \times cc_f \right) \times 10^{-3} - ec_f \right) \times cof_f \times \frac{44}{12} \right] \quad (5)$$

where, ac_f = apparent consumption fuel, cf_f = conversion factor for the fuel to energy units (TJ) on net caloric value basis, cc_f = carbon content (tonne C/TJ i.e. to kg C/GJ), ec_f = excluded carbon defined as carbon in feed-stocks and non-energy use excluded from fuel combustion emissions (Gg C), cof_f = carbon oxidation factor defined as fraction of carbon oxidized (usually the value is 1, reflecting complete oxidation).

Lower values used only to account for carbon retained indefinitely in soot, and (44/12) is the molecular weight ratio of CO2 to Carbon (C). However, 2006 IPCC Guidelines for National Greenhouse Gas Inventories have already predefined a fixed value for CO_2 emission for each source of energy in each country.

Table 1: Variables and Definitions

Variable	Definition
Firm age	Difference between year of study to year of incorporation of the firm
Firm size	Natural log of net sales
Raw material intensity	Expenses on Raw Materials, stores and spares / Net sales
Profit margin	Profit after tax / Net Sales
Capital intensity	Captial / Net Sales
Repairs and maintenance intensity	Repair Expenses/Net Sales
R&D intensity	Research and Development Expenses/Net Sales
Export intensity	Export/Net Sales
Technology import intensity	Expenses on Royalites, technical know-how/Net Sales
Interaction variable 1	Export Intensity x Technology Import Intensity
Labour intensity	Compensation to Employees/Net Sales
Dummy for the environment and pollution control	The dummy variable takes value 1 if the firm reports on the Environment and pollution control expenses, 0 otherwise.
Dummy for the ownership of firm	If the equity share is 10% and above by the multinational firms, this dummy takes value 1, 0 otherwise
Emission intensity	Natural Log of CO2 emission/net sales
Energy Intensity	Natural Log of Energy consumption in BTU/net sales

As for firms in this study for Indian manufacturing, using the IPCC reference approach 1 mmBTU Coal emits 96.36 kgs of CO2; 1 mmBTu Natural Gas emits 52.02 kgs of CO2; and 1 mmBTU Petroleum gas emits 66.72 kgs of CO2. Each firm has specified its primary source of energy consumption in terms of usage of coal, natural gas or petroleum in either tones, kgs, litres or kcal in its energy consumption reports. These values are being converted into mmBTU to further convert into kgs of CO2 emissions using the above specified values. This provides us with absolute value of firm level CO2 emissions. However, Emission intensity is considered as better measurement as compared to emission in absolute form as it is normalized with the output (in this case net sales) of the firm. The definitions of variable used in this study are given in table 1.

Descriptive Analysis

This table shows that with 5436 observations, mean age for the given set of firm for the period under study is 36.413 with standard deviation of 24.712. It has also been found that there are 3560 firms with age less than the mean age whereas 1873 firms which have age higher than mean age.

Table 2: Descriptive Statistics of Full Sample from 2000-14

Variable	Mean	Standard Deviation
Firm Age	36.413	24.712
Log of energy intensity	12.172	3.358
Log of emission intensity	13.549	5.783
Firm size	7.712	1.865
Repair and maintenance intensity	0.486	0.228
Labour Intensity	0.1008	0.189
Interaction variable-1	0.0009	0.005
Research and Development Intensity	0.0037	0.016
Profit Margin	-0.182	11.742
Capital Intensity	0.276	2.262
Raw Martial Intensity	0.017	0.0188
Environment Dummy	0.0413	0.199
Number of observations	5436	

Source: Authors calculation from CMIE Prowess Data.

Average (logarithmic) energy intensity in terms of consumption of physical units for all the firms is 12.172 with a standard deviation of 3.358. Mean of (logarithmic) emission intensity for all the firms comes out to be 13.549 with standard deviation being 5.783. Mean of profit margin here is negative stating that some firms have been incurring losses during this period. Other variables such as repair intensity, raw material intensity, capital intensity, labour intensive have a positive but moderate mean with not very high deviations. As we have used a dummy for environmental and pollution control expenses thus its mean implies that only 4 percent of all the firms have actually reported this variable. Table 2 shows the descriptive statistics for the full sample for 15 year period.

Next in table 3, we categorize the summary statistics of the variables with respect to multinational enterprises and domestic firms, i.e. on the basis their ownership group. We observe that mean age of foreign firms is 45.318, which is higher than that of domestic firms whose mean is 35.924. However, standard deviation of domestic firm's age is higher than that of foreign firms. Emission intensity is slightly higher for domestic firms implying that they emit more than domestic firms with almost same standard deviation. Mean of research and development intensity is very small for both the ownership groups. However, it is slightly higher for foreign firms than the domestic firms implying that foreign firms spend more on research and development. The interaction variable between export intensity and technology import intensity also has a higher mean for multinational entities suggesting that they spend more on technological imports and also has higher export earnings than domestic firms. However, the results also show that domestic firms are more capital intensive whereas foreign firms are more labor intensive as suggested by the mean values of labor and capital intensities. Figure-1 shows the energy consumption by all the firms in terms of their reliance on coal, natural gas and petroleum as a primary source of energy; measured in terms of British Thermal Units (BTU).

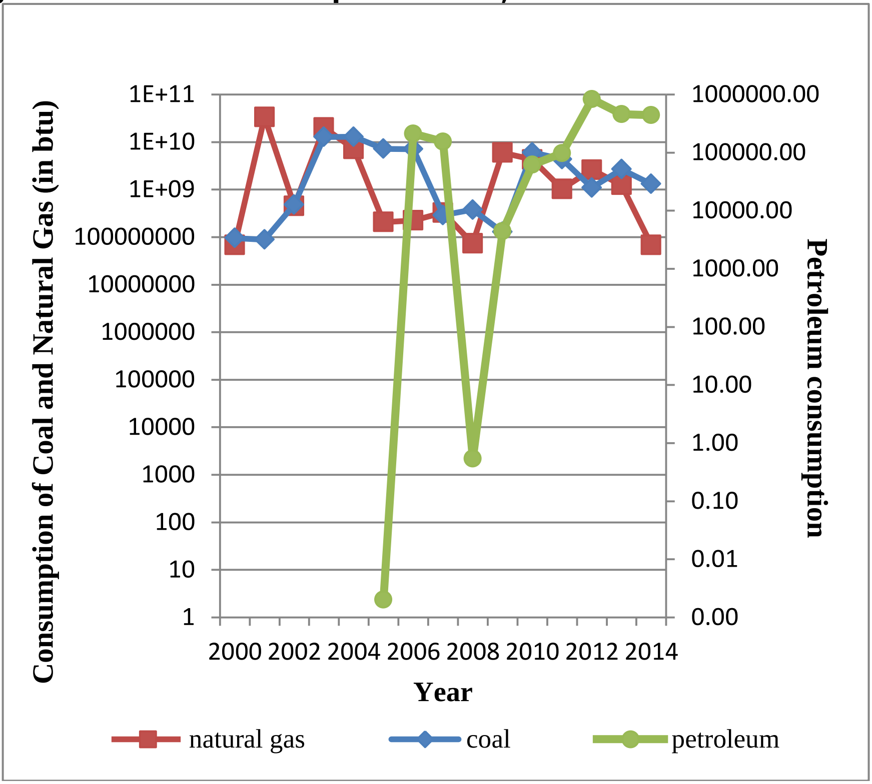
Table 3: Descriptive Statistics by Ownership Group

Firm Characteristics	Domestic Firms		Multinational Firms	
	Mean	Standard Deviation	Mean	Standard Deviation
Firm Age	35.924	24.868	45.318	19.702
Firm Size	7.664	1.870	8.583	1.521
Emission intensity	13.606	5.777	12.516	5.800
Energy Intensity	12.131	3.322	12.920	3.873
Labour Intensity	0.099	0.192	0.131	0.118
Research and development intensity	0.003	0.016	0.006	0.019
Profit Margin	-0.196	12.060	0.072	0.108
Capital Intensity	0.285	2.322	0.098	0.165
Interaction Variable-1	0.0007	0.004	0.004	0.0104
Environment dummy	0.041	0.199	0.035	0.184
Repair Intensity	0.017	0.019	0.018	0.0135
Number of observations	5153		283	

Source: Authors calculation from CMIE Prowess Data.

Figure 1 shows the energy consumption pattern of Indian Manufacturing firms from 2000-2014. As for coal, since 2000, most of the firms have been consuming high quantities of Coal in their production process. There has been an increase in coal consumption from 2003 until 2007. However, there are has been no major fluctuation in the trend of coal consumption during the period under consideration. Natural gas consumption by manufacturing firms has also been high since 2000 with a sharp increase in 2001 falling by almost the same proportion in 2002 and again rising in 2003. Though there have been some variations but majorly there is no change in trend in natural gas consumption as well by manufacturing sector firms. However, in case of petroleum there has a sudden increase in consumption demand in 2005 until 2008 when there has been a sudden downward drift. The demand for petroleum has been highly fluctuating as this source of energy is highly price sensitive.

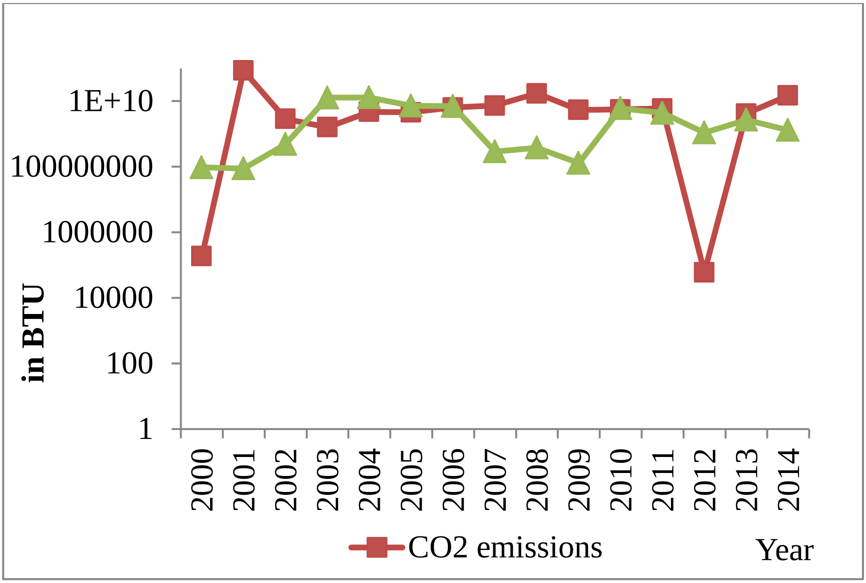
Figure 1: Trends in Consumption of Coal, Petroleum and Natural Gas



Source: Authors calculation from CMIE Prowess Data.

Figure 2 shows the energy consumption of Coal in BTU along with its CO2 emissions for the 15 year period. It shows lesser variations in energy consumption than its emissions. There has been a drastic rise in carbon emissions in 2001 and then a constant trend is followed until 2012 when there has been a sudden decline in emissions from coal and then a major increase in 2013.

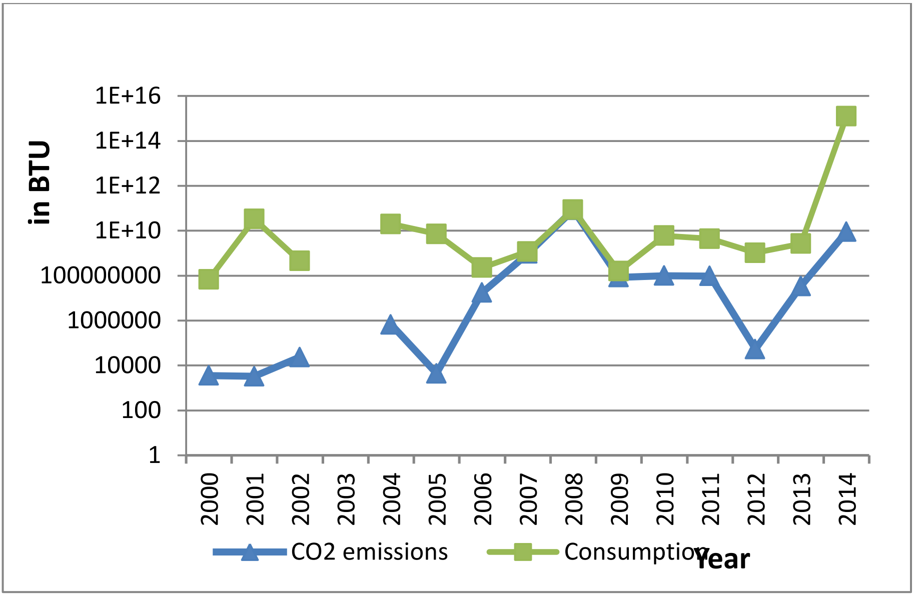
Figure 2: Consumption and Emissions of Coal from 2000-14



Source: Authors calculation from CMIE Prowess Data.

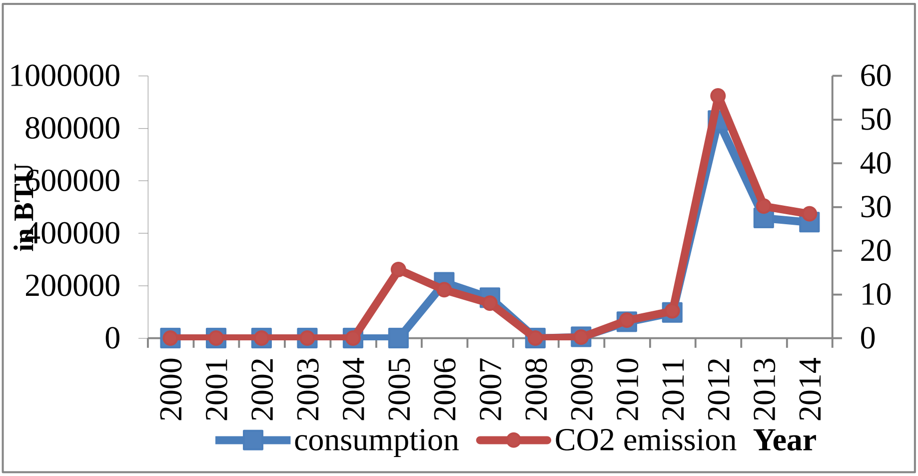
Figure 3 shows energy consumption of natural gas and its carbon emissions for the period under study. Energy consumption has almost followed a constant linear trend until 2013 where a clear upward drift is visible. However, Carbon dioxide emissions have followed a positive trend with slight reduction in 2005 and 2012 but increasing otherwise. Also, to make a note of discontinuity since data was not reported for 2003 for both consumption and emission of natural gas. As for Petroleum, figure 4 shows a positive trend with peaks in 2005 and 2012 for energy consumption which has been rising continuously. This consumption demand is very price sensitive and thus there has been sudden change in energy consumption as and when petroleum prices have changed. Carbon emissions have also followed a similar positive trend with peaks in 2006 and 2012 but have been rising throughout.

Figure 3: Consumption and Emissions of Natural Gas from 2000-14



Source: Authors calculation from CMIE Prowess Data.

Figure 4: Consumption and Emissions of Petroleum from 2000-14



Source: Authors calculation from CMIE Prowess Data.

Determinants of Energy Intensity and CO_2 Emissions

Determinants of Energy Intensity

As discussed above, energy intensity is considered as a proxy for energy efficiency. This section tries to find out firm level determinants of energy intensity. From equation (4), the following regression equation is designed at firm level to estimate the determinants of energy intensity.

$$\begin{aligned}\ln[EI_{it}] = \alpha_o + \beta_1 age_{it} + \beta_2 size_{it} + \beta_3 size^2{}_{it} + \beta_4 CI_{it} + \beta_5 PM_{it} \\ + \beta_6 RMI_{it} + \beta_7 LI_{it} + \beta_8 RDI_{it} + \beta_9 RI_{it} + \beta_{10} envd_{it} \\ + \beta_{11} \mathrm{INV1}_{it} + \beta_{12} \log EM_{it} + \beta_{13} OGD_{it} + \beta_{14} coal_t + \beta_{15} ng_{it} + \mu_{it}\end{aligned} \tag{6}$$

where, CI is capital intensity, PM is profit margin, RDI is research and development intensity, RI is repairs intensity, LI is labor intensity, RMI is raw material intensity, INV1 is the interaction variable for exports and technology imports, ENVD is the dummy variable which takes a value of 1 for firms who have reported environmental and pollution control expenses and 0 otherwise, OGD is the ownership dummy which takes the value 1 for multinational entities and 0 for domestic firms and logEM is natural log of emission intensity at firm level. This estimation process follows standard panel data econometrics. Since the data structure is an unbalanced panel, OLS estimates would not have provided very convincing results therefore, we have tested for both Random Effects (RE) and Fixed Effects (FE) Model.

Equation (6), is estimated both for the fixed and random effects however, the hausman test rejected the null of no significant difference between RE and FE models at 5 percent level of significance, so we have reported the output of the FE model. The results of RE model along with hausman test results for energy intensity estimation are shown in annexure A-1 and A-2 respectively. Table 4 shows the estimation results using Fixed Effects model for estimating Energy Intensity and listing out its determinants.

Table 4: Determinants of Energy Intensity: Fixed Effects Estimates

Variables	Coefficient	Standard error	t-value
Firm age	0.002	0.006	0.33
Firm size	0.445*	0.1355	3.28
Square of firm size	-0.039*	0.009	-4.67
Raw Material intensity	-4.088*	0.216	-18.85
Labour intensity	-1.285*	0.329	-3.9
R&D intensity	-7.905*	2.680	-2.95
Profit Margin	-0.008*	0.004	-2.16
Capital intensity	0.106*	0.025	4.2
Repairs intensity	9.226*	2.717	3.4
Coal dummy	-3.051*	0.462	6.60
Natural Gas dummy	2.872*	0.467	6.14
Interaction variable 1	17.677*	9.553	1.85
Environmental Expenses Dummy	0.0594	0.215	0.28
Natural log of emission intensity	-0.002	0.007	-0.35
Ownership Group Dummy	0.1915	0.206	0.93
Constant	13.412*	0.561	23.9

Note: * implies significance of the coefficient at 5 per cent level of significance.

Source: Authors calculation from CMIE Prowess Data.

On estimating equation (6), we have found that age has turned out to be insignificant. Further, size has a significant positive coefficient stating that with increase in size, energy intensity also increases. This implies that older firms are more energy intensive. Then it also suggests that firms incurring more raw material expenses are less energy intensive. Negative profit margin coefficient suggests that higher energy intensive firms are less profitable. This is in line with the belief that energy efficient firms are more profitable. Further, labor intensity is also significant implying that less labor is required in higher energy intensive firms. Repairs intensity is also significantly positive implying that firms which incur higher repair expenses are highly energy intensive. Capital intensity has a significant positive relation with energy intensity implying that as firms that are highly capital intensive consume higher levels of energy and thus are highly energy intensive. Research and Development intensity has significant negative relationship implying the fact that firms spending more on research and development are less energy intensive, i.e. more energy efficient. However, OGD and Envd have turned out to be insignificant. It is important to note that emission intensity and interaction variable defining an interactive effect of export and technology imports also have no impact on Energy intensity measured in terms of physical consumption of energy. Another important relationship has been found between energy intensity and coal dummy which is significantly negative implying that firms which use more coal are less energy efficient when compared to firms using petroleum. Whereas, the firms that uses more of natural gas as their primary source of energy, are highly energy intensive compared to firms using petroleum.

Determinants of CO2 Emission Intensity

Using panel data econometrics, we have estimated the following regression equation drawn from equation (4) to estimate determinants of emission intensity at firm level.

$$
\begin{aligned}
\ln(EM_{it}) = \alpha_o + \beta_1 age_{it} + \beta_2 age^2{}_{it} + \beta_3 size_{it} + \beta_4 size^2{}_{it} + \\
\beta_5 CI_{it} + \beta_6 PM_{it} + \beta_7 RMI_{it} + \beta_8 LI_{it} + \beta_9 RDI_{it} + \\
\beta_{10} RI_{it} + \beta_{11} envd_{it} + \beta_{12} \mathrm{INV1}_{it} + \beta_{13} OGD_{it} + \\
\beta_{14} coal_{it} + \beta_{15} ng_{it} + \mu_{it}
\end{aligned} \tag{7}
$$

We have checked for both FE and RE models to estimate equation (7). Hausman test conducted to choose between FE and RE model did not reject the null and thus states that there is no significance in RE and FE estimates. Therefore, we use Random Effects Model to estimate the Emission Intensity. FE estimates along with the Hausman test conducted for this estimation has been shown in Annexure A.3 and A.4. Equation (7) has been estimated to find out the determinants of emission intensity and the results are shown in table 7. The results indicate that there exists a positive non linear relationship between emission intensity and firm age while a negative non linear relationship exists between emission intensity and size. A significant negative linear relationship has also been found with size, implying that larger firms emit less. Age is also found to be linearly related to emissions with a positive sign implying that older firms emit more CO2.

As it should have been, research and development has been found to have significant negative coefficient suggesting that firms who spend more on R&D emit less. Repairs intensity also has significant negative relationship implying that firms with higher spending on repairs emit less. Interaction variable which is a product of export intensity and technology imports is also significant with a positive sign stating increased technology imports and high export intensity combined leads to higher emissions. Negative coefficient of ownership group dummy implies that foreign firms are emitting less than domestic firms. Coal dummy and natural gas dummy both are significantly positive implying that firms using more of coal or natural gas emit higher CO2 than firms using petroleum as their primary source of energy.

Table 5: Random Effects Estimation CO_2 Emission Intensity

Variables	Coefficient	Standard error	t-value
Firm age	-0.064*	0.011	-5.84
Square of firm age	0.0004*	0.0001	4.86
Firm size	1.4602*	0.241	6.05
Square of firm size	-0.1075*	0.015	-7.23
Raw Material intensity	-0.121	0.389	-0.31
Labour intensity	-0.0472	0.593	-0.08
R&D intensity	-23.053*	4.838	-4.76
Profit Margin	0.005	0.0076	0.63
Capital intensity	0.054	0.045	1.19
Repairs intensity	12.954*	4.907	2.64
Coal dummy	8.870*	0. .924	9.60
Natural Gas dummy	2.017*	0.943	2.14
Interaction variable 1	32.897*	17.142	1.92
Environmental expenses Dummy	0.271	0.391	0.69
Ownership Group Dummy	-0.717*	0.366	-1.95
Constant	10.219*	0.998	10.23

Note: * implies significance of the coefficient at 5% level of significance.
Source: Authors calculation from CMIE Prowess Data.

CONCLUSIONS

Energy has been recognized as one of the major drivers of growth in any economy. However, we have seen that the consumption of high levels of energy is also hindering the growth objective of an economy due to high amounts of GHG emissions, especially CO2 emissions. These emissions not only hinder the growth process, but also pose challenges to the human capital of any economy in terms of increased climatic temperature, high amount of impurities in air and water etc in long run. Thus, it is an important issue to check for factors causing such emissions and formulate policies to reduce them. In countries like India, where both the population and population density is around the highest extremes in the world, energy consumption demands have been increasing at an exponential rate. With lack of available resources for domestic production to meet such high demands, energy imports have also been increasing. We have looked into the Manufacturing Sector of India, which is one of the major pollutants in the country. Thus, using various estimations and computations, we have been able to deduce the determinants of both Energy Intensity and Emission Intensity. As for Energy Intensity, in terms of energy consumption in physical units, it has been found that size is one of the major determinants of energy intensity. Larger firms undertaking large scale production activities are more energy intensive implying that their energy consumption is higher whereas smaller firms with lower levels of production are less energy intensive. Firms spending more on raw material incur huge costs on them and thus prefer to spend lesser on energy consumption and so are less energy intensive compared to firms spending lesser on raw material purchases.

Labor intensity also affects energy intensity of a firm. Firms employing larger number of employees are found to less energy intensive. Research & Development has been one of the major determinants of energy intensity as firms who spend more on their research and development find out ways on cutting onto their energy consumption demands by using better technology or employing effective labor etc. Profit margins of firms which are highly energy intensive are lower as they are less energy efficient. This implies that high demand of energy entails huge costs and thus lowering the profit margins for them. Further firms which are highly capital intensive also are highly energy intensive. However these firms must try to adapt to newer energy efficient technologies as their capital spending is high and thus can cut down on their energy consumption demands. Furthermore, firms spending more on repairs also have high energy consumption demands and thus are highly energy intensive. It has also been observed that firms relying on coal are less energy intensive than both natural gas and petroleum using firms.

As for CO2 emissions, larger firms with large scale production activities have been found to emit more CO_2 than smaller firms. However, these firms must take advantage of economies of scale and lesser production costs so as to switch on to better energy efficient techniques of production. Moreover, newer firms are also found to be emitting more than older firms with better industry experience. Research & Development plays an important role as firms resorting to more and more research and development are able to find alternative sources and methods of production which in turn lead to reduced CO2 emissions in the environment. As for ownership group, foreign firms have been found to emit less than domestic firms and so it is believed that if local firms learn and adapt technologies used by foreign firms, they can also cut down on their emissions.

One of the major observations in terms of the relationship between Energy intensity and Emission intensity has been that firms using Coal as primary source of energy in their production are less energy intensive and high emission intensive as compared to those using natural gas and petroleum. Therefore, it is implied that Coal is one of the highest CO_2 emitting source of energy. Even lesser quantities of coal can lead to high amount of emissions. However, it has been found that majority of the firms in Indian Manufacturing sector are highly reliant on Coal. Thus, it is proposed that these firms must switch to other sources of energy, especially to renewable ones in order to deal with the major issue of high GHG emissions in the country. This would not only reduce the harmful emissions in the environment but in turn would also lead towards higher growth targets.

A.1 Random Effects Estimation for Energy Intensity

Variables	Coefficient	Standard error	t-value
Firm age	0.004	0.005	0.91
Firm size	0.397*	0.115	3.45
Square of firm size	-0.046*	0.007	-6.54
Raw Material intensity	-3.314*	0.184	-17.93
Labour intensity	-1.835*	0.280	-6.55
R&D intensity	-14.288*	2.299	-6.21
Profit Margin	-.0111*	0.003	-3.10
Capital intensity	.135*	0.021	6.34
Repairs intensity	11.417*	2.325	4.91
Coal dummy	-3.206*	0.421	-7.61
Natural Gas dummy	3.0216*	0.432	6.99
Interaction variable 1	18.880*	8.111	8.11
Environmental expenses Dummy	.0413	0.185	0.22
Ownership Group Dummy	-.142	0.173	-0.82
Natural log of emissions	.0809*	0.006	11.67
Constant	14.666*	0.602	24.35
Hausman test statistics	74.01***		

Note: * implies significance of the coefficient at 5 percent level of significance.
Source: Authors calculation from CMIE Prowess Data

A.2 Fixed Effects estimation for Emission intensity

Variables	Coefficient	Standard error	t-value
Firm age	-0.056*	0.011	4.89
Square of firm age	0 .001*	0.001	3.85
Firm size	1.281*	0.254	5.04
Square of firm size	-0.096*	0.015	-6.16
Raw Material intensity	-0.113*	0.409	-0.28
Labour intensity	0.422	0.591	0.71
R&D intensity	-11.596*	4.818	-2.41
Profit Margin	0.008	0.007	1.11
Capital intensity	0.028	0.045	0.63
Repairs intensity	8.689	4.879	1.78
Coal dummy	8.870*	0.924	9.60
Natural Gas dummy	2.016*	0.943	2.14
Interaction variable 1	25.220	17.139	1.47
Environmental expenses Dummy	0.303	0.386	0.79
Ownership Group Dummy	-0.224	0.370	-0.60
Constant	3.183*	1.307	2.43
Hausman test statistics	19.26		

Note: * implies significance of the coefficient at 5 percent level of significance.
Source: Authors calculation from CMIE Prowess Data.

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