CO2 Emission and Firm Heterogeneity: A Study of Metals Metal based Industries in India

K., Narayanan and Sahu, Santosh Kumar

Indian Institute of Technology Bombay

22 February 2012

CO_2 Emission and Firm Heterogeneity: A Study of Metals & Metal based Industries in India

K. Narayanan
Institute Chair Professor
Department of Humanities & Social Sciences, IIT Bombay, Mumbai, India
knn@iitb.ac.in

Santosh K. Sahu
Doctoral Student
Department of Humanities & Social Sciences, IIT Bombay, Mumbai, India
santoshkusahu@gmail.com

Abstract

Industrial energy efficiency has emerged as one of the key issues in India. The increasing demand for energy that leads to growing challenge of climate change has resulted major issues. It is obvious that high-energy intensity leads to high carbon intensity of the economy. This paper is an attempt to estimate the firm level CO_2 emissions for the metals and metal based industries in Indian manufacturing. Calculation of firm level emissions is carried out following IPCC reference approach methodology of Carbon Dioxide emission from fuel combustion. We tried to find out the inter-firm differences of CO_2 emission in the metals and metal based industries. In finding out the determinants of CO_2 emission at firm level we have examined whether the firm heterogeneity matters for the differences in emission at firm level. Data for this study is collated from the CMIE PROWESS online database from 2000-2008, IEA energy statistics and IPCC conversion factors for each of the fuel types.

JEL Classification: Q4, B23

Keywords: CO_2 emission, Firm heterogeneity, Panel data econometrics, Metals and Metal based industries

(Presented in the IEG International workshop titled "Towards Greening the Economy" on 22-02-2012)

CO_2 Emission and Firm Heterogeneity: A Study of Metals & Metal based Industries in India

K. Narayanan[1] & Santosh Kumar Sahu[2]

1. Introduction

At a macroeconomic perspective, there is no consensus on the effect of international trade on the environment, and in particular on the effect of trade on global emissions. Neither the theoretical nor the empirical literature provides a clear cut answer to the link between trade and CO_2 emissions. Very few studied have attempted to estimate emission at the firm level. Studies in eco-innovation can be broadly divided in to two categories. A first mainstream research deals with the drivers of eco-innovation strategies. The seminal work by Jaffe and Palmer (1997), that studies environmental innovation (R&D and patents) at industry level, was followed by Brunnermeier and Cohen (2003), which employs panel data on manufacturing industries to provide new evidences on the determinants of environmental innovation, measured by number of patents. The European setting has recently been the source of some interesting evidence for instance; Rennings et al., (2003) exploit OECD survey data in order to investigate whether environmental auditing schemes and pollution abatement innovation are correlated. Mazzanti and Zoboli (2008) present evidence for the manufacturing sector at a district level, focusing on an extended set of drivers (environmental R&D, policy induced costs, industrial relations, and other innovations). Frondel et al., (2004) use an OECD survey dataset on manufacturing firms and study internal firm-based strategies, external policy variables, and test drivers for end-of-pipe measures or integrated cleaner production processes. A second stream of research is focused on environmental innovation and employment effects. The main contributions in this stream include Rennings and Zwick (2001) and Pfeiffer and Rennings (1999). However, studies pertaining to link firm level emission and firm heterogeneity are scanty. One of the major reasons is non availability of emission data at the firm level. In this connection this study is an attempt to compute the firm level CO_2 emission following on IPCC reference approach and relate it with the firm heterogeneity.

[1] Institute Chair Professor, Department of Humanities & Social Sciences, IIT Bombay, Mumbai, knn@iitb.ac.in
[2] Santosh K. Sahu, Doctoral Student, Department of Humanities & Social Sciences, IIT Bombay, Mumbai santoshkusahu@gmail.com

2. Review of literature

This section of the paper attempts to look at the mainstream research similar to the objective of this work. The study carried out by Rennings and Zwick (2001) is based on a sample of eco-innovative firms for five EU countries in manufacturing and service sectors. This is rather a unique study which provides evidence related to manufacturing sector but also includes some evidence concerning eco-innovations in service sector too. They find that in most of the firms employment does not change as a consequence of innovations. The econometric results show that, apart from some product innovations, eco-innovation typologies do not influence the level of employment, though as expected, according to their evidence environmentally oriented innovations seem to lead to, a skills based effect. Also, end-of-pipe innovations are related to a higher probability of job losses, while innovations in recycling have a positive effect on employment. Employment effects may thus be unevenly distributed, with strong negative effects from environmental strategies/policies on low skills intensive industries and potentially positive effects on other industries. It could also be argued that product and process eco-innovation strategies may bring about (potentially negative) net effects on employment, attributable to a destruction of the low skilled labour force (administrative staff) and a creation of high skilled positions (R&D).

There is a complementary stream of literature that has focused on the various static and dynamic relationships between eco-innovation, environmental performances and firm performances. Konar and Cohen (2001) investigated the effect on firms' market performance of tangible and intangible assets, including two environmental performance-related elements as explanatory factors. Cohen et al. (1997) also analyzed the relationship between environmental and financial performances. Overall, these authors found that investing in a 'green' portfolio did not incur a penalty and even produced positive returns.

Gray and Shadbegian (1995) used total factor productivity and growth rates for firms over 1979-1990 as performance indicators to test the impact of environmental regulations and pollution abatement expenditures. They found that $1 more expenditure on abatement is associated with more than 1$ worth of productivity losses. Analysis on variations over time or growth rates, the relationship between abatement costs and productivity found not to be significant. Greenstone (2001) estimated the effects of environmental regulations, using data for 175 million observations of firms in the 1967-87 US censuses of manufacturers.

According to the study environmental regulations negatively affect growth in employment, output and capital shipments.

The EU based study by Ziegler et al., (2008), focused on (1) the effects of environmental strategies on the stock performances of corporations using standard cross section/panel approaches and (2) 'event' studies that analyze whether there are exogenous unexpected policy effects on the short term performance of environmentally minded firms. The latter are criticized for their intrinsic very short term focus. Although valuable, and based on official datasets, they conclude that the evidence focusing on stock market performance is limited since the majority of firms; especially in Italy, are of medium or small sized and do not appear in stock market data. Innovation dynamics are close to productivity trends which in the end are the main engines of firm performance.

Doonan et al. (2005) examined the role of communities to create incentives for local industrial facilities to reduce pollution. They found that firms face both internal and external pressures to improve their environmental performance. Using primary data collected for 750 pulp and paper industries in Canadian pulp and paper industries during 1992 they further found that the Government policies are much of a barrier for the Canadian pulp and paper industries. However, financial and consumer markets are not most important barriers. They found that education status of employee is one of the important determinants of environmental performance. The regulatory intervention is also found as the major determinants of environmental performance of the pulp and paper industries. Unlike other industrial sectors, the pulp and paper industries produce energy as by-products.

In case of the Indian manufacturing industries, firm level energy intensity and their determinants has been studied majorly by Goldar (2011) and Sahu & Narayanan (2011). Both the studies use Indian manufacturing data from CMIE PROWESS online database and follow structure-conduct-performance theory of the firm and analyzed the determinants of energy intensity at firm level. Energy intensity can be considered as a proxy for energy efficiency of firm and hence, the inter-firm differences can be obtained from the above studies. However, what is relevant to our study is the main hypothesis that increasing environmental efficiency by environmental innovations strengthens competitiveness and the firm heterogeneity. This paper is embedded in focusing on the effects of firm heterogeneity on emission (CO_2 emission) intensity.

3 A brief note on the Indian metals & metal based industries

According to Schumacher and Sathaye (1998) six industries in Indian manufacturing are identified as energy intensive ones: aluminum, cement, fertilizer, iron and steel, glass, and paper. Together these industries account for 16.8% of value of output in Indian manufacturing and consume 38.8% of fuels consumed in this sector. The iron and steel industries hold a considerable share within these energy intensive industries. In 1993, it accounted for 46.5% of value of output within the six industries and for 7.8% in the manufacturing sector. Production in the iron and steel industries has been increasing over the last 20 years. From 1973-1993 the real value of output has increased by an annual average of 7.6%. Following the fertilizer and cement industry, iron and steel shows third highest growth in the group of energy intensive industries. The growth of real value of output was stable at around 7.8% during the pre-liberalization period (1973-1985) and decreased significantly to 6.2% in the following period of economic liberalization (1985-91) accounting for lower than average growth in both the group of six energy intensive industries and total manufacturing. In 1991, the liberalization process culminated and real value of output growth increased substantially by 10.2% until 1993.

The iron and steel industries consume 13.2% of total fuels in the Indian manufacturing industries. Within the group of energy intensive industries; the share of fuels consumed per unit of output is lowest in iron and steel industries (11.5%). Fuel costs per unit of output are 27% less than the average for the six energy intensive industries. However, fuel costs per unit of output are still 70% higher than the average of total manufacturing unit fuel costs. Besides fertilizer production, the iron and steel industry has been least energy intensive not only in 1993, but almost over the whole time period. Only in the early years of the time period under consideration iron and steel production was relatively more energy intensive. A peak can be observed in 1978-79. Overall, despite its fluctuating pattern the iron and steel industry shows a relatively stable trend in energy intensity. Primary sources of energy utilized in the iron and steel industries encompass coking coal, non-coking coal, liquid hydrocarbons, and electricity. Out of these coking coal holds the major share of energy used (65-80%). While coking coal, non-coking coal and liquid hydrocarbons are primarily used in integrated steel production, electricity by far presents the major input for steel making in small firms using electric arc furnaces or induction furnaces.

Besides technology and process related factors there are several other general factors that affects specific energy consumption in steel plants, the product mix, for example, has impact on energy use. The manufacture of more complex and high quality products increases overall energy intensity. In addition, there are factors specific to Indian case those should be taken into account when trying to understand the higher energy consumption of Indian steel firms. They include the quality of raw material that is available to Indian industries, the scale of operation, firm size and size of coke ovens, firm utilization factors, economic and political incentive structures for adoption of technology updates and modernization, and the installation of energy saving and recovery systems.

The Indian iron and steel sector has been under strict government control for a long period since independence. Government intervention took place in the form of both direct and indirect intervention. Direct intervention happened in the form of Government control over distribution of available steel among consumers and indirect intervention took the form of price control and import levies. After independence, the government took full control over the iron and steel sector and established a policy of restricting development of new integrated steel plants to the public sector. In 1959, the government formally approved the setting up of privately owned EAF based mini plants by modifying the industrial policy resolution-1956. The policy change was due to sustained shortage of steel in the Indian economy.

Prices of different steel products were determined by the Government and announced by the Joint Plant Committee (JPC); a body constituted in 1964 under the Iron and Steel Control Order. From the main producers about 80% of production of the plants under the Steel Authority of India Limited (SAIL) and about 65% of the production of the private company (TISCO) were regulated by the JPC. Prices were fixed by the JPC according to normative costs and certain levies like the Steel Development Fund (SFD), Engineering Goods Export Assistance Fund (EGEAF), JPC Cess, Freight Equalization Fund (FEF) etc. The distribution policy aimed at ensuring an equitable distribution among end-users and meeting the requirements of the priority sectors like railways, defense and power. Together with the price policy the Government aimed at ensuring iron and steel availability to consumers according to their priority at reasonable prices throughout the country.

From 1972, due to impeded growth in the steel industry, the Government introduced dual pricing in the iron and steel industry. Certain steel products such as heavy structurals, flats and railway materials were made available at low prices. For other products, prices were allowed to increase significantly. In 1982, the Bureau of Industrial Costs and Prices (BICP) officially observed what had been implied for a long time; Costs and prices of different categories of iron and steel did not show any systematic relationship under dual pricing. A comparison of actual and calculated ‘normated’ costs for each steel item revealed that only two items, i.e. heavy structurals and H. R. coils had been priced adequately. Some products, such as pig iron and semi-finished steel, were substantially underpriced, others substantially overpriced. In general, pig iron, semi-finished products and long products produced by the integrated steel plants were underpriced. Prices for products, however, produced out of these semi-finished products were determined in the market. As a consequence many steel rerolling companies were set up that used cheap semi-finished products for producing final products that could be sold at free market prices.

Since 1992, the Government has gradually decontrolled prices and distribution of steel. The new policy still includes control over distribution to priority sectors. Private production, however, has been totally decontrolled. Yet, freight equalization has been abandoned subject to certain conditions. Furthermore, import duties have been substantially reduced by 20% and more on imports of various semi-finished and finished steel products. In the progress of industrial development the Government has also provided facilities to support mini-steel plants. These include (i) liberal import of melting scrap and sponge iron without import duty, (ii) free diversification into all grades of carbon and alloy steels, including stainless steel, (iii) installation of captive rolling units, (iv) addition of balancing facilities like continuous casting machines, heat treatment furnaces, etc.

Based on the different policy interventions, technology differentials in production, firm size and product mix differentials could account for large heterogeneity among firms in this sector. Hence, there is a possibility of consumption of different sources of fuel in this sector. That makes a firm in this sector either energy efficient or energy intensive. Based on the primary energy consumption the emission of the firm is associated. Therefore, higher dependence on fossil fuel as primary source of energy might involve higher emission for those firms. The next section of this work is focused on the conceptual framework to compute the CO_2 emission from fossil fuel and further describes the econometric framework in relating firm heterogeneity and emission in this sector.

4. Conceptual framework, methodology and the sample

One of the objectives of this work is to estimate the CO_2 emission at firm level. Further, we econometrically model the factors explaining determinants of inter-firm differences in the CO_2 emission. We begin explaining the construction of the firm level CO_2 emission for the Indian metals and metal based industries.

4.1 Construction of firm level CO_2 emission at firm level

This study uses the IPCC reference approach, which refers as a top-down approach using aggregate information of fossil fuel consumed, to calculate the emissions of CO_2 from combustion of mainly fossil fuel. However, the study has some data limitations as emission calculation is carried out for the first time at firm level in Indian manufacturing firms. Data is collected from the Center for Monitoring Indian Economy data-base; PROWESS 4.0. This data is a combination of the annual audited balance sheet (that gives information of the firm characteristics) and energy consumption at firm level. Therefore, firms that don't report energy consumption are dropped from the active data sheet. Further, information given on CMIE data report seven types of energy sources consisting of 44 sources of energy. However, we have only considered the type-1 (primary) energy consumption of the firms. Also, since we are following the IPCC reference approach, we have considered only the fossil fuels consumed by the firms. The IPCC reference approach of estimating emissions from fossil fuels is as follows:

$$CO_2 = \sum_{i=n}\left[\left(\left(ac_f \times cf_f \times cc_f\right)\times 10^{-3} - ec_f\right)\times cof_f \times \frac{44}{12}\right] \tag{1.1}$$

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 CO_2 to Carbon (C).

Further, following Chen et al. (2010) we construct the firm level emission as:

$$C_t = \sum_{i=1}^{3} C_{i,t} = \sum_{i=1}^{3} E_{i,t} \times NCV_i \times CEF_i \times COF_i \times (44/12) \tag{1.2}$$

Where, C_t = flow of carbon dioxide with unit of 10,000 tons, NCV_i = net calorific value provided by IEA energy statistics for India, 2011, CEF_i = carbon oxidization factor provided by 2006 National Greenhouse Gas Inventories in IPCC, COF_i is the carbon oxidization factor set to be one in this study. Therefore, following equation (1.2) in Indian metal and metal based industries the calculated CO_2 emission coefficient for coal is 2.0483 (kg CO_2/ kg coal), for oil 3.272 (kg CO_2/ kg oil) and for natural gas 2.819 (kg CO_2/m^3 natural gas).

4.2 The model

Following Copeland and Taylor (2003) and Forslid et al. (2011) assuming each firm produces two outputs: a manufactured good (*x*) and emission (*e*), the testable implication of the study follows a log linear relation of the following type:

$$\ln\frac{e}{x} = \left(\vec{fh}\right) \tag{1.3}$$

Where, $\ln\frac{e}{x}$ =Natural log of firm level emission intensity and $\vec{fh}$ is a vector representing firm characteristics. We use an unbalanced panel data for the estimation of equation (1.3). Following similar framework as in Goldar (2011) and Sahu and Narayanan (2011) for the Indian manufacturing industries, the general form of equation (1.3) is estimated with the following econometric specification:

$$\begin{aligned}\ln\frac{e}{x_{it}} &= \alpha_{it} + \beta_1 ci_{it} + \beta_2 li_{it} + \beta_3 ei_{it} + \beta_2 s_{it} + \beta_2 s_{it}^2 + \beta_2 ag_{it} + \beta_2 ag_{it}^2 + \\ &\quad \beta_2 t_{it} + \beta_2 rd_{it} + \beta_2 mne_{it} + \varepsilon_i + \mu_{it}\end{aligned} \tag{1.4}$$

Where *ci*: capital intensity, *li*: labour intensity, *ei*: energy intensity, *s*: size of the firm, s^2: Square of size of firm, *ag*: age of the firm, ag^2: Square of age of firm, *t*: technology import intensity of the firm, *rd*: Research and Development intensity of firm and *mne*: Multinational affiliation of the firm.

4.3 The sample and variables construction

In this section, we describe the sample and the variable construction to estimate the model. Different empirical works that study reasons for energy (in)efficiencies pay attention to the market share or value added to the industry output and find the evidence that it can make a contribution to the explanation of inefficiencies as the factor of market power (Hrovatin and Urib, 2002). It is worth mentioning, that fossil energy resources are characterized by the considerable undesirable outcome (such as CO_2 emissions) and still their share in total energy generation is dominant, while the role of renewable energy sources is comparatively low, though extended recently. We have selected the following variables those influence the emission intensity of firms.

Firms can gain technological advancement not only through their own innovations but also through purchases of new capital or intermediate goods from other sectors. Capital intensity measured in terms of net fixed asset (i.e. total fixed asset net of accumulated depreciation; include capital, work-in-progress and revalued assets) as a proportion of net sales. Similarly, labour intensity of the firm is calculated as the ratio of wages and salaries paid to the workers to net sales. Energy-intensity (proxy for energy efficiency) is measured as a summation of all possible sources of energy consumed by a firm in British thermal unit (BTU) as a proportion of sales. This will give us whether the energy efficient firms are less emitting or vice versa.

In most of the productivity studies of four factors of production, energy consumption is considered as one of the indicator for innovation. This implies that in cost minimization a firm can shift from one source to the other and it has been observed that firms do shift from energy intensive to efficient. Hence, it will be of interest to check the relationship between energy efficiency and emission at the firm level. Size of the firm is the proxy for several effects as observed by Bernard and Jensen (2001). Size of firm is one of the components of firm heterogeneity. Because of scale economics bigger firms might use the efficient fuel and emit less. In the present study, firm size is measured by the natural log of total sales. There could be a non-linear relationship between emission intensity and firm size. Age of the firm is calculated as the deference between years of the study to year of the incorporation of the firm as reported in the CMIE database.

Technology import intensity is defined as the expenses on import of capital goods and royalty and technical fees payments in foreign currency, to net sales of the firm. Higher the technology import it is assumed that firm might be emitting less as technology advancement of the firm might enable the firm to be energy efficient and emit less. R&D intensity is also one of the innovation strategies that might help firms in emitting less. Here, we define R&D intensity as the ratio of R&D expenditure to net sales. There is empirical evidence that foreign-owned companies tend to be more efficient in energy conservation (Faruq and Yi, 2010) and, at the same time, there is also evidence in Zelenyuk and Zheka (2006) that reveals a negative correlation between foreign ownership and firm's environmental efficiency level. We have created a dummy to capture the MNE affiliation, where firm belonging to foreign affiliation takes a value 1 and the domestic firms takes a value of 0.

4.4 Descriptive analysis

From figure-1 we can observe that the aggregate CO_2 emission of the metals and metal based firms in Indian manufacturing are fluctuating over the period with a linear increase in the trend from 2000-2008. One of the reasons of this type of changes might be due to the sample size each year. The sample size each year is given in figure-1 where the sample consists of 400 firms as the highest number of firms in 2004 and 280 firms as the least in 2008. However, expecting in 2000, 2001, 2003 and 2006, the rest of the years firms have shown higher emission. In 2002 the sample firms has the highest emission as compared to minimum in 2003. Figure-2 presents the average CO_2 emission intensity of the metals and metal based firms in Indian manufacturing from 2000-2008. The mean energy intensity of the sample also shows an increasing trend. From the figure we can observe that in 2000, 2006 & 2007 the emission of the metals and metal based industries, are showing higher emission as compared to the other years. In both the figures we can observe that the series are fluctuating and don't represent a certain pattern. The only difference between both the figures is that the first figure is based on the absolute emission however; the second figure represents output adjusted average emission for the sample.

Figure-1: Aggregate CO_2 emission in metals and metal based industries in India (MT CO_2)

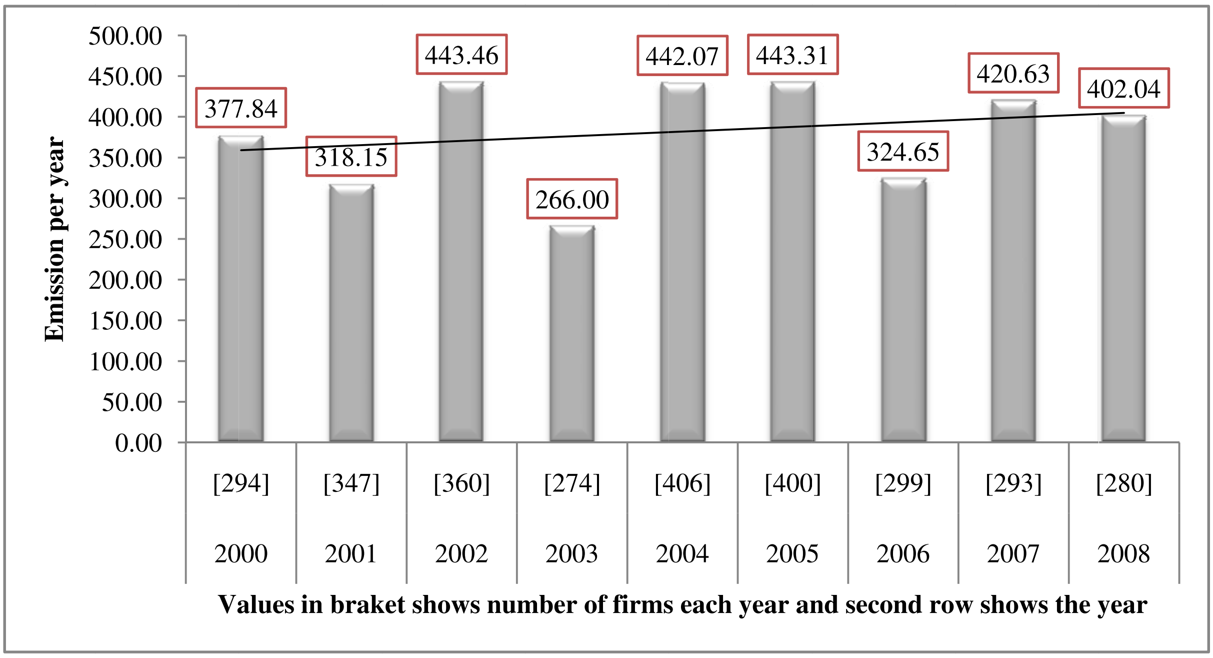


Figure-2: Annual average CO_2 emission in metals and metal based industries in India

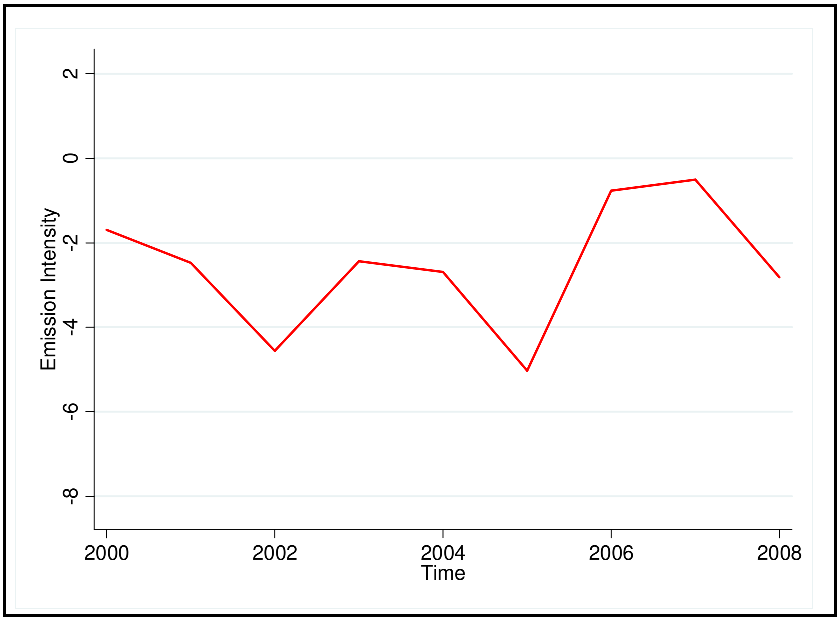
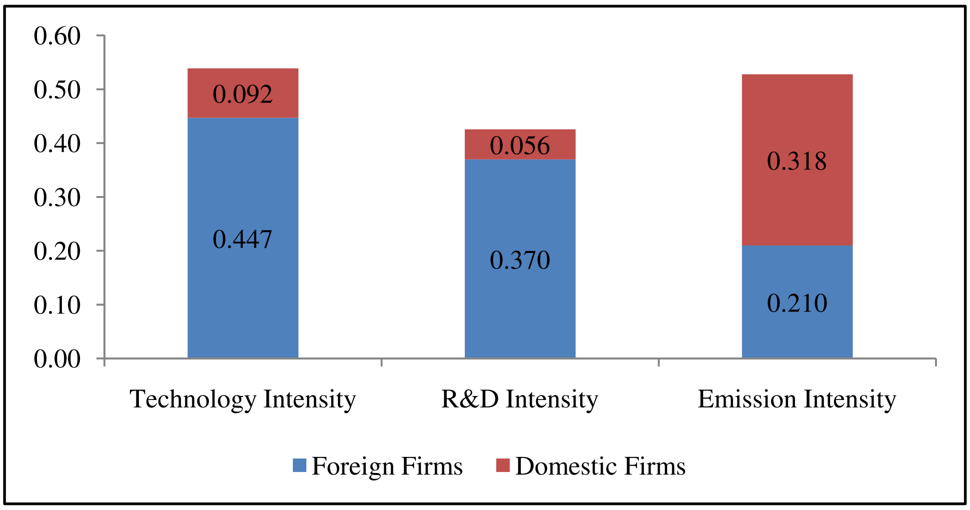


Figure-3: Emission, technology and R&D intensity of domestic and foreign firms



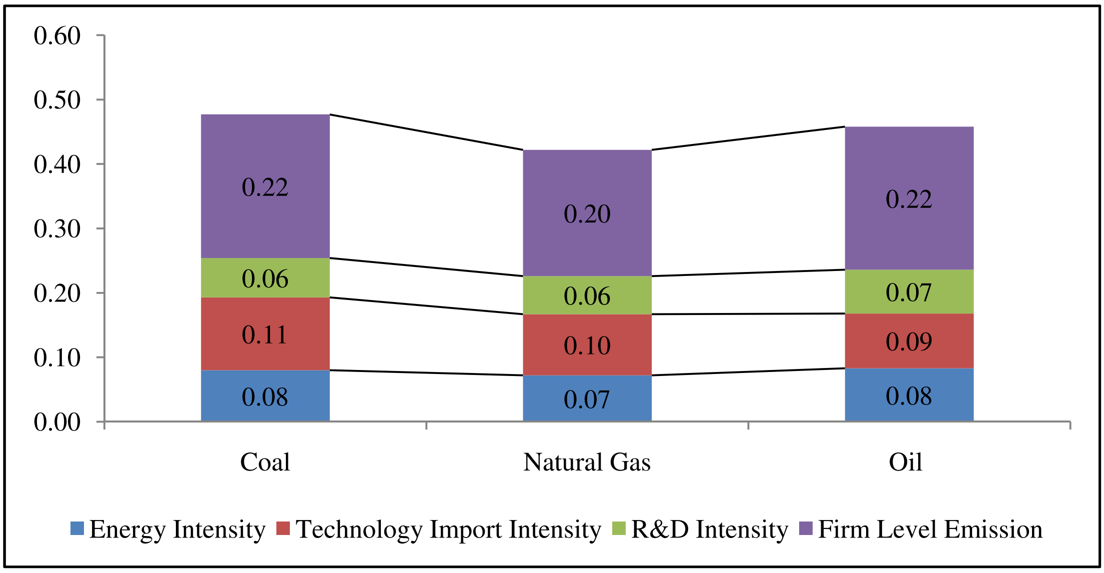
One of the indicators of firm heterogeneity is multinational affiliation of firms. In figure-3 we have plotted the technology import, R&D and the emission intensity of firms. As a result of technology import and investment on research & development a firm might lead to reduce the emission, therefore we need to differentiate between foreign and the domestic firms. From figure-3 we can see that foreign firms are higher technology intensive and higher R&D intensive however, the domestic firms are higher emitting. Emission intensity is not widely differenced, but domestic firms emit more than the foreign firms. Nine years data of metals and metal based industries of Indian manufacturing states that the CO_2 emission is higher for the domestic firms (0.32) as compared to the foreign firms (0.21). The mean of other firm characteristics is given in table-1. From the table we can see that domestic firms are capital and labour intensive. However, foreign firms are energy efficient.

Table-1: Comparison of firm characteristics between foreign and domestic firms

Firm Type	Capital Intensity	Labour Intensity	Energy Intensity
Domestic	1630.445	147.590	0.119
Foreign	129.089	8.833	0.077

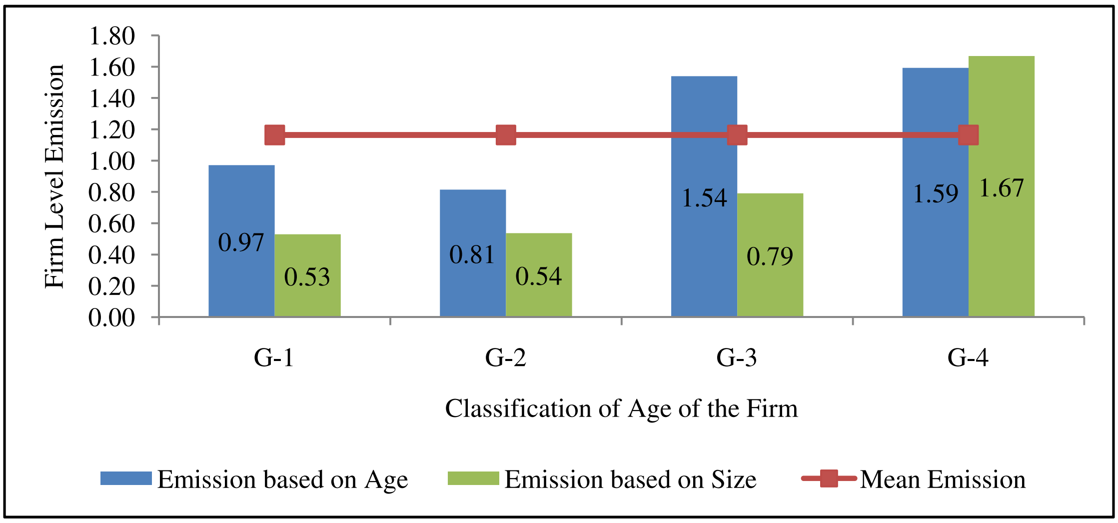
As metals and metal based industries differ in consuming primary energy sources, it is of interest to classify firms based on primary energy consumption. Figure-4 gives the comparison of energy intensity, technology import, R&D and firm level emission of sub-sample classified under different energy consumption. From the figure we can see that energy intensity is higher for firms using coal and oil, however firms using natural gas are energy efficient. In case of technology intensity we can observe that firms using coal as primary source of energy are importing higher technology as compared to firms using natural gas and oil. However, oil consuming firms are higher R&D intensive as compared to the other two classifications. Emission is similar for firms using coal and oil and found to be lesser for the natural gas consuming firms.

Figure-4: Energy, technology, R&D and emission intensity between three fuel sources



One of the major indicators of firm heterogeneity is size and age of the firm. We have classified the sample based on the age and size distribution of the firms and relate with firm level emission. Figure-5 presents group of firms classified based on size and age. For the age of the firms we have created four classifications. The classification (G-1) represents firms aged between 1-10 years old, G-2 represents 11-25, G-3 represents 26-50 and G-4 represents firms older than 51 years old. Similarly, in case of the size of the firms, G-1 represents 10th percentile of the sample, G-2 represents 25th percentile, G-3 represents 50th percentile and G-4 represents higher than the 50th percentile. Emissions from the G-2 (Medium aged firms) are found to be the least as compared to the other classifications. Higher emitting firms fall at the fourth classification of firms those are older ones. In case of the size of the firms, the bigger firms are emitting higher as compared to the smaller firms. There is an increasing trend visible for emission in case of size of the firm and emission intensity in the sample. The relationship between firm size and emission intensity is tested with an econometric model in the next section.

Figure-5: Emission based on groups of firm classified for age and size



5 The empirical results

The econometric estimate of the study is narrated in this section. We have computed the correlation matrix for the select variables. From the correlation coefficients it is seen that energy intensity is statistically significant and positively related to emission intensity, where as size of the firm is negatively related and statistically significant to emission intensity. Capital intensity, age of the firm, technology import intensity and R&D intensity is also found to be positively related to firm level emission.

Table-2: Correlation matrix

	Capital Intensity	Labour Intensity	Energy Intensity	Size of the firm	Age of the firm	Technology Import Intensity	R&D Intensity	Firm Level Emission
Capital Intensity	1.000							
Labour Intensity	0.846	1.000						
Energy Intensity	0.004	-0.016	1.000					
Size of the firm	0.345	0.298	-0.235	1.000				
Age of the firm	0.104	0.138	0.020	0.172	1.000			
Technology Import Intensity	0.590	0.479	0.039	0.387	0.219	1.000		
R&D Intensity	0.092	0.155	0.107	0.127	0.040	0.109	1.000	
Firm Level Emission	0.024	-0.015	0.582	-0.232	0.077	0.117	0.007	1.000

Equation 1.4 is estimated using pooled OLS, fixed and random effect of panel data econometrics. Based on the coefficient of the Hausman statistics, the fixed effect estimates are selected over the random effect estimates. Methodologically, result of fixed effect is

better as compared to the pooled OLS estimates. Hence we have focused on the results of the fixed effect model in table-3. As seen in equation 1.4 the econometric model is a semi log model and in the construction of size of the firm we have defined size as natural log of net sales, hence the econometric equation turns out to be a double log model. Hence the coefficients of the model are the elasticity. However, detailed results of the pooled OLS and random effect are given in annex-1.

Table-3: Determinants of CO_2 emission

Variables	Coefficient	Standard Error	t value
Capital Intensity	0.003	0.001	2.200**
Labour Intensity	-0.005	0.003	-2.520***
Energy Intensity	1.293	0.164	4.870***
Size of the firm	0.043	0.154	2.280***
Square of Size of the firm	-0.132	0.048	-2.730***
Age of the firm	0.013	0.004	3.280***
Square of age of the firm	0.004	0.003	-2.010***
Technology Import Intensity	-0.539	0.274	-1.970**
R&D Intensity	-0.016	0.104	-2.160**
MNE	-0.042	0.168	-0.250
Constant	-1.305	0.141	-9.290
R^2 (overall)	0.289		
R^2 (within)	0.288		
R^2 (between)	0.294		
(F test that a u_i=0) F(2324, 621)	8.290***		
F(7,621)	20.65***		
Number of observations	2953		

Two parameters are considered for the technology sourcing in this study, namely the technology import intensity, and the R&D intensity. In the estimated coefficients, we can observe that the technology import intensity is statistically significant at 1% and carries a negative sign, which means firms importing more technology are emitting less. Hence, higher the import of technology lower will be the emission of the firms. Research and development intensity has turned out to be statistically significant and negatively related to emission intensity. This means that firms investing more in research and development are emitting less. Therefore, role of technology sourcing of firm make firms emitting less in case of the metals and metal based firms in Indian manufacturing firms. Based on this result, we can assume that the technology sourcing and the R&D investments of the firms might be considered as the eco-innovation strategies of the firms.

In this study, since the sample consists of very small as well as very large firm, we have estimated a non-linear relationship between firm size and CO_2 emission. The results indicate a positive and negative coefficient for size and size square variable. This implies that very large and very small firms are emitting less and the medium sized firms are emitting more. We also found a nonlinear relationship between emission and age of firm indicating an inverted 'U' shape relationship as the coefficients are statistically significant at 1% and carries positive and negative sign for the age and age square of firms. That in turn indicates that both older and the younger firms are less emitting, whereas the median firms are emitting more. These results are akin to the literature on environmental Kuznets curve for both developed and developing countries. That is as both size and age of the firm increases, the CO_2 emission also increases. However, with increasing awareness and building capabilities, the emission level starts declining beyond a point.

The capital intensity has a positive relation with the emission intensity of the firm, and is highly significant at 1%. Which in turn means that, the firms with the larger capital are emitting higher, compared to firms with the smaller capital. According to Narayanan (1998), accumulation of technological capabilities through learning by doing is facilitated by the skilled manpower employed in a firm. The calculation of the labour intensity is quite similar to Narayanan (1998), hence labour intensity can also refer as a proxy for skill manpower. The result of the labour intensity is statistically significant at 1% and negatively related to emission intensity. Therefore, labour intensive firms are emitting less as compared to the less labour intensive metals and metal based firms.

The MNE affiliation is constructed as a dummy variable. This variable is not found to be significant but looking at the descriptive statistics on the relationship of MNE, R&D and technology import intensity we can find that foreign firms are importing more technology and investing more in R&D as compared to the domestic firms. Even in case of the emission we can see that there is difference between the domestic and foreign firms. Hence, we assume that the foreign affiliation is captured either in the technology import or in the research and development expenses of the firm in the model. Further, energy intensity of firm is found to be positively related and statistically significant with the emission intensity. This implies energy intensive firms are also emission intensive.

6 Summary

The increasing concern on climate change, green house gases, and emissions are matter of concern not only for developed countries but also for the developing as well as the underdeveloped countries. In addition, concerns have been also 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. India being one of the largest and rapidly growing developing countries the issue of emission needs special focus. Analysis on the emission from the industries of Indian economy should not be at the aggregate level/ at national level. Specific interest must be given for the sub-sectors as well.

In this connection, this work is an attempt to compute CO_2 emission of metals and metal based firms in Indian manufacturing industries from 2000-2008 following the IPCC reference approach. The results indicate that there are differences in firm-level emission intensity and they, in turn, are systematically related to identifiable firm heterogeneity. This study found size, age, energy intensity and technology import intensity as the major determinants of CO_2 emission intensity of Indian metal and metal based firms. In addition capital and labour intensity of the firms are also related to the firms' emission intensity.

Indian metals and metal based industries play a significant role in the country's economic growth. The major contribution directs the attention that this sector is having a stronghold in the traditional sectors, such as infrastructure & constructions, automobile, transportation, industrial applications etc. However, in global competitiveness in this sector Indian metals and metal based industries have to upgrade the technologies and should achieve for energy as well as emission efficiency. In addition, specific policy measures should be formulated to encourage medium sized firms to upgrade technology and invest in research and development pertaining to eco-innovation to become emission efficient. Metals and metal based industries are one of the energy intensive industries in Indian manufacturing. As this study indicates that higher emission intensity is positively related to energy intensity of firms, reducing energy intensity might help firms to emit less. Therefore, research and development related to fuel switching, green energy etc. should be given due attention. The contribution of this paper lies in estimating CO_2 emission at the firm level and analyzing the factors that explain inter-firm variation in CO_2 emission.

Annex-1: Estimates of Pooled OLS and Random effect models

Variables	Coefficients	Robust Standard Error	t value	Coefficient	Standard Error	z value
	Pooled OLS			Random Effect		
Capital Intensity	0.002	0.001	2.320	0.003	0.001	2.700
Labour Intensity	-0.002	0.001	-1.710	-0.002	0.001	-2.630
Energy Intensity	5.096	0.863	5.900	3.409	0.120	6.430
Size of the firm	1.219	0.113	5.830	0.881	0.074	5.870
Square of Size of the firm	-0.174	0.038	-4.550	-0.085	0.023	-3.640
Age of the firm	0.011	0.004	2.890	0.013	0.004	3.280
Square of age of the firm	0.003	0.002	-1.790	0.002	0.001	-2.010
Technology Import Intensity	-0.896	0.378	-2.370	-0.848	0.103	-8.240
R&D Intensity	-0.071	0.123	-1.580	-0.023	0.034	-0.680
MNE	-0.038	0.180	-0.210	-0.042	0.168	-0.250
Constant	-2.850	0.238	-11.960	-2.473	0.198	-12.460
F(10, 2942)	101.130					
R^2 (overall)	0.429			0.338		
R^2 (within)				0.423		
R^2 (between)				0.411		
Root MSE	1.076					
Wald chi^2				1516		
Number of observations	2953					

References

Arimura T. Hibiki A. Katayama H. (2008), Is a voluntary approach an effective environmental policy instrument? A case for environmental management systems, Journal of Environmental Economics and Management, vol.55, pp.281-95

Bernard, A. B. and Jensen B. (2001), Why Some Firms Export?, NBER Working Paper No. W8349

Brunnermeier S. Cohen M. (2003), The Determinants of Environmental Innovation in US Manufacturing Industries, Journal of Environmental Economics and Management, vol. 45, pp. 278-93

Cohen M. Fenn S. Konar S. (1997), Environmental and Financial performance: are they related?

Cole M.A., Elliott R. Shimamoto K. (2005), Industrial characteristics, Environmental regulations and air pollution: an analysis of the UK manufacturing sector, Journal of environmental economics and management, vol.50, n.1, pp. 121-43

Collins A. Harris R. (2005), The impact of foreign ownership and efficiency on pollution abatement expenditures by chemical plants: some UK evidence, Scottish Journal of Political Economy, vol.52, n.5

Doonan J, P. Lanoie, and B. Laplante, (2005), Determinants of environment performance in Canadian pulp and paper industries: An assessment from inside the industry, Ecological Economics, Vol. 55, pp. 73-84

Faruq, H. A., and David T. Yi., (2010), The Determinants of Technical Efficiency of Manufacturing Firms in Ghana. Global Economy Journal, Vol. 10, Issue 3, Article 7

Foulon J. Lanoie P. Laplante B. (2002), Incentives for Pollution control: Regulation or Information? Journal of Environmental Economics and Management, vol.44, pp.169-187

Frondel M. Horbach J. Rennings K. Requate T. (2004), Environmental Policy Tools and Firm-level Management Practices: Empirical Evidence for Germany, CAU economics working paper n.2, Department of Economics, Kiel

Goldar, B. (2011), Energy Intensity of Indian Manufacturing Firms: Effect of Energy Prices, Technology and Firm Characteristics, Science Technology Society, Vol. 16, No. 3, pp. 351-372

Gray W. Shadbegian R. (1993), Environmental regulation and manufacturing productivity at the plant level, discussion paper, US Department of Commerce, Centre for Economic Studies, Washington D.C.

Greenstone M., (2001), The Impacts of Environmental Regulations on Industrial Activity: Evidence from the 1970 and 1977 Clean Air Act Amendments and the Census of Manufacturers, NBER working paper n.8484, NBER

Hrovatin, N., and Urib, S. (2002), The Determinants of Firm Performance after Ownership Transformation in Slovenia. Communist and Post-Communist Studies, Vol. 35, pp. 169-190

Jaffe A. Palmer K. (1997), Environmental regulation and innovation: a panel data study, The review of economics and statistics, vol.79, n.4, pp. 610-619

Johnstone N. (2007), Environmental Policy and Corporate Behaviour, Edward Elgar, Cheltenham, UK

Konar S. Cohen M. (2001), Does the market value environmental performance?, The review of economics and statistics, vol.83, n.2, pp.281-89

Kumar N. and N.S. Siddharthan (1994), "Technology, Firms Size and Export behavior in Developing Countries: The Case of Indian Enterprises, Journal of Development Studies, Vol. 31, No. 2, pp. 289-309

Mazzanti M. Zoboli R. (2008), Complementarities, firm strategy and environmental innovations. Environmental Sciences 5(1), 17-40

Pfeiffer F. Rennings K. (1999), Employment impacts of cleaner production, Discussion paper n.46 Centre for European Economic Research (ZEW), Mannheim

Rennings K. Ziegler A. Ankele K. Hoffmann E. Nill J. (2003), The influence of the EU environmental management and auditing schemes on environmental innovations and competitiveness in Germany. An analysis on the basis of case studies and a large scale survey, Discussion paper 03-14, ZEW, Mannheim

Sahu, S. K., Narayanan, K., (2011), Determinants of Energy Intensity in Indian Manufacturing Industries: A Firm Level Analysis, Eurasian Journal of Business and Economics, Vol. 4, No 8, pp. 13-30

Schumacher and Sathaye (1998), India's Iron and Steel Industry: Productivity, Energy Efficiency and Carbon Emissions, Ernest Orlando Lawrence Berkeley National Laboratory, LBNL-41844

Zelenyuk, Valentin, and Vitaliy Zheka. (2006), Corporate Governance and Firm's Efficiency: the Case of Transitional Country, Ukraine. Journal of Productivity Analysis 25: 143-168.

Ziegler A., Schroder M., Rennings K. (2008), The effect of environmental and social performance on the stock performance of European corporations, Environmental & Resource Economics, Vol. 40, pp. 609-680