Reduction in Carbon Emissions Intensity among Indian Manufacturing Firms and Its Impact on Their Export Competitiveness, 2009-2013

Bishwanath Goldar,* Yashobanta Parida** and Deepika Sehdev***

Abstract: Between 2002-03 and 2012-13, energy consumption intensity and carbon dioxide (CO_2) emissions intensity of Indian manufacturing declined by about 30 percent. During the last 10 to 15 years, Indian manufacturing has achieved, at the aggregate level, an average rate of reduction in energy intensity and CO_2 emissions intensity in the range of 3 to 3.5 percent per annum. During 2009-10 to 2012-13, a majority of India's organized-sector manufacturing plants achieved a rate of reduction in CO_2 emissions intensity of about 10 percent per year or more, which is obviously a significant achievement. Did this plan or strategy of Indian manufacturing firms aimed at reducing energy consumption and carbon emissions from manufacturing activity cause any loss of competitiveness, particularly export competitiveness? This is the main question investigated in the paper. A related question is what factors determined the inter-plant and inter-firm variations in the extent of reduction achieved in carbon emissions. The analysis is carried out with the help of unit-level data of *Annual Survey of Industries* (ASI) for the years 2009-10 to 2012-13 and a panel dataset of about four thousand manufacturing companies drawn from the *Ace Equity* database covering the period 2009-10 to 2013-14. The analysis is done in two steps. First, an analysis is undertaken of the inter-plant and inter-firm variation in the extent of reduction achieved in CO_2 emissions intensity during the period under study. An attempt is made to explain why some plants/ firms have achieved a relatively much greater reduction in their carbon intensity. Then, in the second step, an econometric analysis of export performance is carried out by estimating a model of export behavior of manufacturing firms. In the econometric model of export performance, CO_2 emissions intensity is taken as an explanatory variable along with other determinants of exports, such as firm size and import intensity. From the estimates of the model of export performance of Indian manufacturing firms obtained in the study it appears that containment of CO_2 emissions in the manufacturing firms did not cause any major loss in their export competitiveness. Rather, reduction in CO_2 emissions was found to be positively associated with increases in exports.

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1. Introduction

There have been several studies on energy intensity and Carbon Di Oxide (CO_2) emissions intensity[1] of Indian manufacturing industries (for example, Reddy and Ray, 2010; Sahu and Narayanan, 2011, 2013; Goldar, 2011, 2012, 2013; Gupta and Sengupta, 2013; and Goldar and Bhalla, 2015). The studies have mostly been undertaken on the basis of industry level data or firm (company) level data. An important finding of these studies is that energy intensity and CO_2 emissions intensity of Indian manufacturing has been on the decline since the early 1990s. Goldar (2012) notes that, between 1992-93 and 2008-09, energy intensity of Indian manufacturing fell by about 60 percent (average annual rate of fall of about 4%). This is in line with the estimates of CO_2 emissions intensity of Indian manufacturing made by Reddy and Rao (2010) who found an average annual rate of fall of about 3.6% in the period 1992 to 2002. According to the estimates of Sahu and Narayanan (2011), the average energy intensity of Indian manufacturing firms fell by about 25 percent between 2000 and 2008, i.e. a rate of fall of about 3.5 percent per annum. Goldar and Bhalla (2015) observe that CO_2 emissions intensity of Indian manufacturing fell by about 14 percent between 2007-08 and 2012-13, i.e. a rate of fall of about 3 percent per annum. They point out that a similar decline in energy intensity and CO_2 emissions intensity of Indian manufacturing took place also in the previous five years. Thus, in the period 2002-03 to 2012-13, CO_2 emissions intensity of Indian manufacturing declined by about 30 percent, which is obviously a significant achievement. Based on the estimates presented in the studies mentioned above, it may be concluded that in the last 10 to 15 years, India manufacturing has reduced its energy intensity and CO_2 emissions intensity by about 3 to 3.5 percent per year, on an average.

In the United Nations Framework Convention on Climate Change (UNFCCC) summit in 2009, India had made a commitment to reduce its carbon emissions intensity by 20–25% as compared to the 2005 level over the next 11 years. Recently, in October 2015, India has announced her climate action plan for 2030 which is called *Intended Nationally Determined Contributions* in official language. As announced, India plans to reduce emissions intensity by 33 to 35 percent from the 2005 level by 2030. If the observed past trend in carbon emissions intensity of Indian manufacturing continues till 2030, the reductions in carbon emissions intensity made by the

[1] Energy intensity is measured by the ratio of energy consumption to output. Similarly, CO_2 emissions intensity is defined as ratio of CO_2 emissions to output.

manufacturing sector between 2005 and 2030 will far exceed the national level target (because 3% average fall for 25 year comes to approximately 53%, and at 3.5% annual rate of fall, the fall over 25 years is about 60%). However, one may ask whether it would be possible to continue the past trend in energy and CO_2 emissions intensity of Indian manufacturing. Arguably, further reductions in energy and CO_2 emissions intensity may prove more and more difficult and this may slow down the pace of reduction in energy and CO_2 emissions intensity. An important issue here is the international competitiveness of Indian manufacturing firms and plants. If attempts are made to sustain (and possibly accelerate) the current pace of reduction in energy and carbon intensity of Indian manufacturing by imposing a carbon tax or though emissions trading[2] and that causes a significant loss of competitiveness with adverse impact on export performance and growth, it may be difficult to maintain the downward trend in energy and carbon emissions intensity of Indian manufacturing that has been observed for the last 10 to 15 years. This is the main issue which motivates this paper.

It is rather simplistic to assume or assert that if a manufacturing firm reduces its CO_2 emissions intensity induced by environmental regulations, say a carbon tax or a market based instrument for pollution control, its cost of production will go up, which will in turn adversely affect its export competitiveness.[3] There is a substantial body of literature which would make one believe that a properly designed environmental regulation leading to better environmental performance by an industrial firm need not cause its competitiveness to go down — but may instead enhance it. This view, known as the Porter hypothesis, can be traced to the works of Porter and van der Linde (1995), Jaffe et al. (1995) and Jaffe and Palmer (1997). There is empirical support for this view (for instance, see Lanoie et al., 2008; Leeuwen and Mohnen, 2013; Rubashkina et al., 2014). The explanation for the favourable impact of environmental regulation on firm competitiveness lies in the innovations stimulated by the environmental regulations which raises firm productivity and hence competitiveness. A condition, however, is that the environmental policies be well designed to stimulate proper techno-organizational innovations (Costantini and Mazzanti, 2012).

The study undertaken by Costantini and Mazzanti (2012) is quite relevant in the context of the present paper. They have empirically analyzed the export performance of EU firms and found that the environmental and energy taxation does not always cause a fall in export performance. Rather, a positive effect of energy and environment tax on export performance is found for firms

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[2] An initial step towards this direction is the Performa, Achieve and Trade (PAT) Scheme which was launched by the Indian government in 2012. The first phase of three years under this scheme was from April 2012 to March 2015. The scheme covers 478 largest capacity production units in eight energy intensive industries in India including iron and steel, aluminium and thermal power plants. The scheme is expected to save energy use in those industries by about 4% (thus reducing CO_2 emissions) in the first round of three years.

[3] Goldar and Bhalla (2015) study the effect of carbon tax on cost of production of Indian manufacturing firms by taking a cost function approach and make an assessment of the consequent effect on the firms' export performance.

belonging to the high technology sector, and a positive effect of energy tax on export performance is found for firms belonging to the medium-low technology sector. According to the authors, in the former case, the favourable effect is traceable to technological advances and innovation, whereas in the latter case, the energy tax pushes the firms to improve input-use efficiency which in turn raises their competitiveness. One needs to recognize that there are certain negative impacts from energy and environmental taxation inasmuch as these tend to raise the costs of production. But, the findings of Costantini and Mazzanti (2012) indicate that in certain categories of firms, the negative impacts are more than offset by certain positive impacts generated by the energy/environment tax. The positive gains arise primarily from the tax induced technological advances and innovations as well as the drive to cut down resource wastages triggered by the tax. Does such neutralization of negative effects of carbon taxation through innovation and waste elimination take place only in industrially advanced nations, or can such neutralization occur also in developing countries such as India? This is an important issue. The econometric analysis presented in this paper attempts to address this issue in the context of Indian manufacturing.

The rest of the paper is organized as follows. The next two sections, Sections 2 and 3, present an analysis of carbon intensity in Indian manufacturing based on ASI data (*Annual Survey of Industries*, Central Statistics Office, Government of India) for the period 2009-10 to 2012-13. Section 2 is based on published two-digit and three-digit industry level data (according to *National Industrial Classification*, NIC, 2008), whereas Section 3 presents an analysis based on unit level data of ASI for the years 2009-10 and 2012-12. Sections 4 and 5 are based on firm (company level) data, drawn from the *Ace Equity* database. Panel data for about 4000 manufacturing companies for the period 2008-09 to 2013-14 are used for the analysis. Section 4 examines the reduction in CO_2 emissions intensity achieved by different manufacturing companies between 2009-10 and 2013-14 and makes an attempt to explain the inter-firm variations in the extent of reduction in CO_2 emissions intensity achieved. Section 5 is devoted to an analysis of export performance of manufacturing firms. An export function is estimated from firm-level panel data in which CO_2 emissions intensity is taken as one of the explanatory variable. The aim is to ascertain whether reduction CO_2 emissions intensity has an adverse effect on export performance. Finally, in Section 6, the key findings are summarized and some concluding remarks are made.

2. Industry level analysis of CO_2 emissions

ASI publications provide details of energy consumption for different three-digit and two-digit industries (according to *National Industrial Classification*, NIC). These data have been used to make an estimate of the level of CO_2 emissions and CO_2 emissions intensity (ratio of carbon emissions to output). For coal and electricity (purchased), the consumption data are available in physical quantity. For oil, only the value of consumption is given. This has been converted into quantity (fuel oil) by using the price of fuel oil.[4] The published data clubs other energy sources into the head 'others'. This has been split into natural gas and 'other fuels' by using the unit level data of ASI. The expenditure on natural gas has been converted into quantity using the price of natural gas. The rest of the expenditure on energy has been treated as cost of fuelwood and a quantity figure has been derived by using the price of fuelwood. Having obtained, the quantity of five types of fuel, the computation of CO_2 emissions has been done by using emission factors which have been taken from diverse sources. The estimated CO_2 emissions have been divided by output (with price correction) to compute CO_2 emissions intensity.

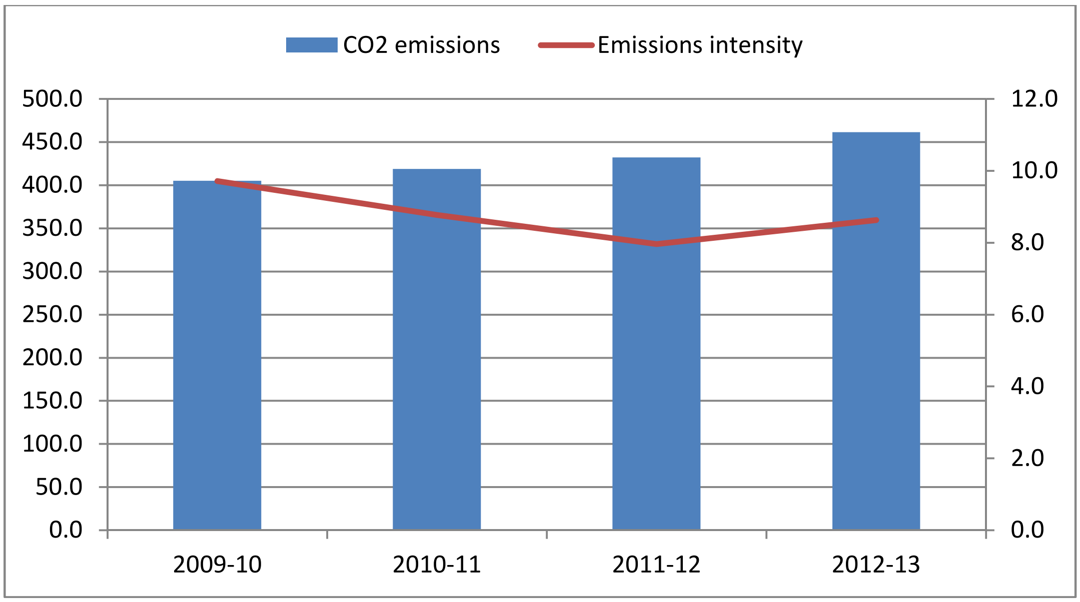

Fig. 1: Indian manufacturing, CO_2 emissions and emissions intensity

Notes: CO_2 emissions are measured in million tonnes and CO_2 emissions intensity in tonnes of CO_2 per million rupees of output (PMRO) at 2011-12 prices (in the right scale). Source: Authors' computations from ASI data.

Figure 1 shows the level of CO_2 emissions of Indian manufacturing (organized[5]) and CO_2 emissions intensity in the years 2009-10 to 2012-13. The estimated CO_2 emissions for 2012-13 is about 460 million tonnes,[6] and estimated emissions intensity is about 8.6 tonnes of CO_2 per

[4] Note that when a petroleum product is used as a feedstock, for example use of naphtha in fertilizer units or use of natural gas in petrochemical units, it is included in materials in the ASI data.
[5] The estimates based on ASI covers only the organized sector (i.e., factories employing 10 or more workers with power or 20 or more workers without the use of power).
[6] According to the estimates of Goldar and Bhalla (2015), the level of CO_2 emissions of Indian manufacturing in 2012-13 was about 600 million tonnes. The difference in estimates is due to differences in the emission factors used. One important difference is that the estimates presented in the paper involve breaking up of published data on energy cost under the head "others" into two parts: natural gas and other fuel, which has been done with the help of unit level data on industrial plants. Such segregation was not done in Goldar and Bhalla (2015). According to the *2014 Report on Trends in Global CO_2 Emissions* brought out by the PBL Netherlands Environmental

million Rs of output (PMRO) at 2011-12 prices. The estimates indicate that CO_2 emissions intensity fell by about 11 % between 2009-10 and 2012-13 (annual growth rate of about -3%).

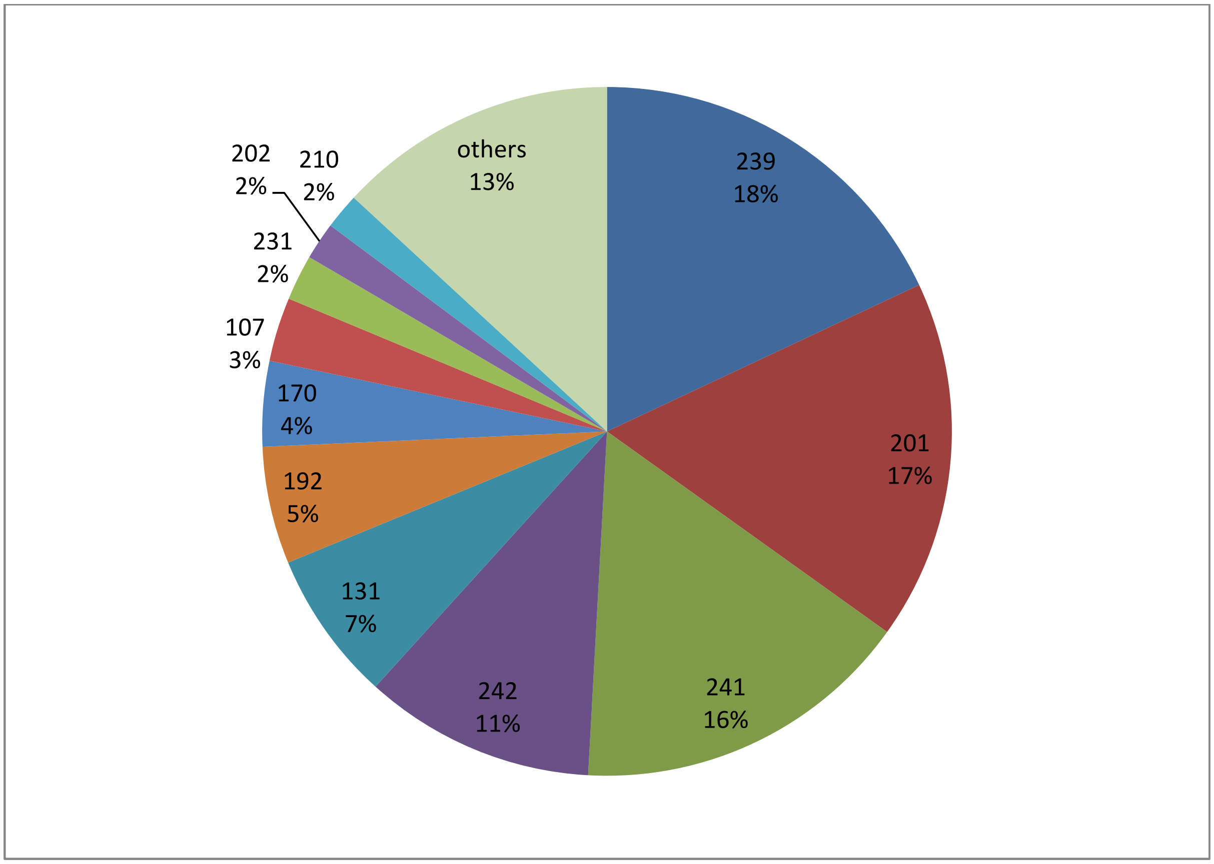

Fig. 2: Shares (%) of three-digit industries in CO_2 emissions of Indian manufacturing, 2012-13

Note: Three-digit industry codes are: 239, Manufacture of non-metallic mineral products other than glass; 201, Manufacture of basic chemicals, fertilizer and nitrogen compounds, plastics and synthetic rubber in primary forms; 241, Manufacture of basic iron and steel; 242, Manufacture of basic precious and other non-ferrous metals; 131, Spinning, weaving and finishing of textiles; 192, Manufacture of refined petroleum products; 170, Manufacture of paper and paper products; 107, Manufacture of 'other' food products (including sugar, bakery, cocoa and chocolate); 231, Manufacture of glass and glass products; 202, Manufacture of other chemical products; and 210, Manufacture of pharmaceuticals, medicinal chemical and botanical products.

Source: Authors' computations from ASI data.

The shares of different three-digit industries in total CO_2 emissions of Indian manufacturing in 2012-13 are shown in Figure 2. The shares of top 11 industries in terms of emissions are shown

Assessment Agency, CO_2 emissions of Indian manufacturing (in 2013) was about 0.5 billion tonnes. This is consistent with the figure of 460 million tonnes obtained in this study.

separately, and the rest has been clubbed. It is seen from the figure that non-metallic mineral products, basic metals, basic chemicals and petroleum refining account for a dominant portion of total CO_2 emissions of Indian manufacturing.

Figure 3 shows for select two-digit industries, CO_2 emissions intensity in the years 2009-10 and 2012-13 and the annual rate of decline between the two years. The industries selected are the ones that rank high in terms of level of CO_2 emissions. The figure brings out that in almost all cases, there has been a fall in CO_2 emissions intensity. Interestingly, in several cases the rate of fall in CO_2 emissions intensity is high – in some cases it exceeds 10% per year.

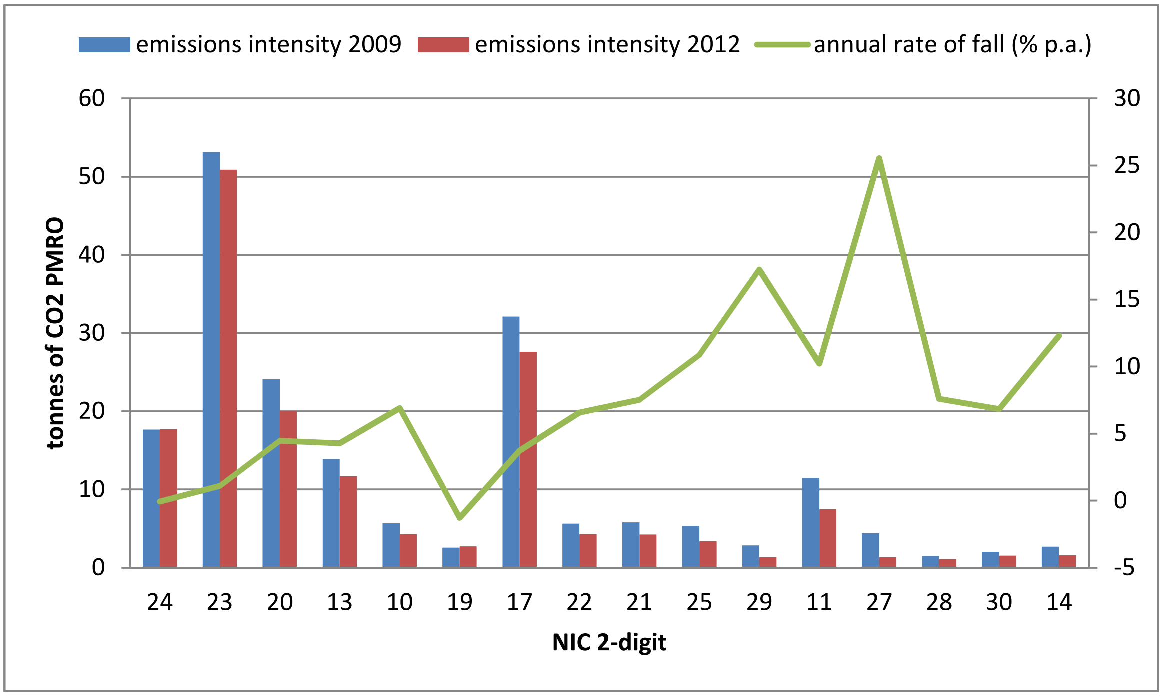

Fig. 3: CO_2 emissions intensity, 2009-10 and 2012-13, and the annual rate of fall (right scale), Select two-digit industries

Notes: Two-digit industries with CO_2 emissions above one million tonnes have been chosen for the graph. The industries are arranged according the level of emissions (emissions are highest in industry 24 and least in industry 14, among the 16 considered). The industries are: 24, Manufacture of basic metals; 23, Manufacture of non-metallic mineral products; 20, Manufacture of chemicals and chemical products; 13, Manufacture of textiles; 10, Manufacture of food products; 19, Manufacture of coke and refined petroleum products; 17, Manufacture of paper and paper products; 22, Manufacture of rubber and plastic products; 21, Manufacture of pharmaceutical, medicinal chemical and botanical products; 25, Manufacture of fabricated metal products except machinery and equipment; 29, Manufacture of motor vehicles, trailers and semi-trailers; 11, Manufacture of beverages; 27, Manufacture of electrical equipment; 28, Manufacture of machinery and equipment n.e.c.; 30, Manufacture of other transports equipment; and 14, Manufacture of wearing apparel.

Source: Authors' computations from ASI data.

It is interesting to observe that in general there is an inverse relationship between the share of a two-digit industry in aggregate CO_2 emissions of the manufacturing sector, and the rate of fall in CO_2 emissions intensity achieved by that industry. Industries 24, 23, 20 and 13 together accounted for 75% of manufacturing sector CO_2 emissions and these industries on average achieved a rate of fall in CO_2 emissions intensity of about 2.5% per annum. On the other hand, industries 11, 27, 28, 30 and 14 together accounted for about 3% of manufacturing sector CO_2 emissions and these industries, on an average, achieved a rate of fall in CO_2 emissions intensity of about 12.5% per annum. Thus, while some two-digit industries have achieved a high rate of fall in CO_2 emissions intensity, these industries account for only a small part of aggregate CO_2 emissions of the manufacturing sector, and the impact at the aggregate level is therefore small.

3. Plant level analysis of CO_2 emissions intensity

Plant-level analysis of CO_2 emissions intensity has been undertaken for the years 2009-10 and 2012-13. Plant-level data on consumption of coal, oil, electricity, natural gas and other fuel (treated as fuelwood) has been converted into CO_2 emissions using emission factors and after obtaining total CO_2 emissions for each plant, it has been divided by the value of output to compute CO_2 emissions intensity.

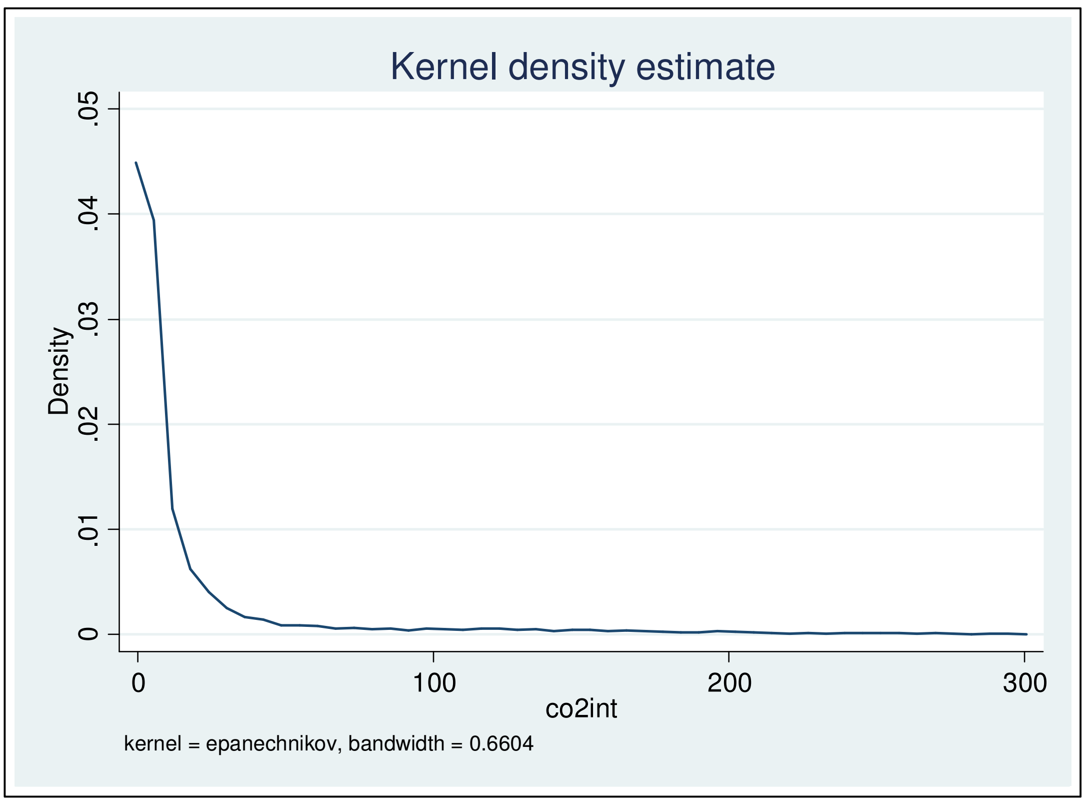

Fig. 4: Kernel density, CO_2 emissions intensity, manufacturing plants, 2009-10

Source: Authors' computation based on unit level ASI data.

Kernel density estimate of CO_2 emissions intensity (tonnes PMRO) of manufacturing plants is presented in Figure 4 (based on data on about 39,000 plants). It is seen there is a high concentration at low levels. In preparing the graph, exceptionally high values have been left out (top 1% is trimmed). The mean CO_2 emissions intensity across plant is found to be 15.6 tonnes PMRO and the median is 2.9 tonnes PMRO.

3.1 Explaining inter-plant variation in CO_2 emissions intensity

An attempt has been made to explain inter-plant variation in CO_2 emissions intensity by estimating a regression equation. The explanatory variables used are plant size (measured by logarithm of fixed capital stock), size squared, capital intensity (measured by logarithm of capital-labour ratio), capital intensity squared, and dummy variables for new plants (started production after 1990), and plants belonging to private and public limited companies. The use of size and size-squared permits a non-linear relationship between firm size and CO_2 emissions intensity. The same applies to the use of capital intensity variable with its squared term. To incorporate industry-wise diversity in the estimated model, industry fixed effects have been allowed in the model at 5-digit level of NIC. The estimated regression equation is shown in Table 1.

Table 1: Determinants of CO_2 emissions intensity of manufacturing plants, 2009-10, Regression Results

Dependent variable: CO_2 emissions intensity (tonnes of CO_2 PMRO)

Explanatory variable	Coefficient	t-ratio
Size	-3.40	-4.96***
Size squared	0.12	5.79***
Capital intensity	1.45	2.32**
Capital intensity squared	-0.067	2.61***
New plant (dummy)	-1.66	5.43***
Plant belongs to a Private limited company (dummy)	-1.51	-4.00***
Plant belongs to a Public limited company (dummy)	-0.68	-1.28
Industry dummies (NIC 5-digit level)	Included (569 categories)	
Constant	33.0	11.23***
R-squared	0.53	
F-statistic (Prob.>F)	18.85 (0.0000)	
No. of observations	38,116	

, * statistically significant at five and one percent level respectively.

Source: Authors' computation based on unit level ASI data.

The regression results indicate a U-type relationship between plant size and CO_2 emissions intensity after controlling for industry affiliation and some other factors. As size increases, CO_2 emissions intensity falls. But, beyond a threshold, CO_2 emissions intensity increases with plant size. With capital intensity, an inverted U-type relationship is indicated by the regression results. Up to a stage, a positive relationship holds between capital intensity and CO_2 emissions intensity, and beyond that, CO_2 emissions intensity goes down with increases in capital intensity (this phase probably reflects substitution of energy by capital).

The regression results indicate that, other things remaining the same, a new manufacturing plant has a lower CO_2 emissions intensity. This is presumably the effect of recent vintage of technology (the argument is that equipment embodying more recent technology would be more energy saving).

As regards, the form of business organization, a plant belonging to a private limited company seems to have a relatively lower CO_2 emissions intensity. The comparison is primarily with plants belonging to proprietorships and partnerships. A negative coefficient is found also for plants belonging to public limited companies. However, in this case, the coefficient is not statistically significant.

3.2 Change between 2009-10 and 2012-13

Having analyzed the inter-plant variation in the level of CO_2 emissions intensity, attention is now shifted to the rate of change over time. To analyze this aspect, plant level CO_2 emissions intensity has been computed for the year 2012-13. For about 18,000 manufacturing plants, data on CO_2 emissions intensity could be matched between 2009-10 and 2012-13. To take care of inflation, the CO_2 emissions intensity in 2009-10 has been expressed in 2012-13 prices. The distribution of CO_2 emissions intensity for 2009-10 and 2012-13 among the common plants is depicted in Figure 5 (the value of CO_2 emissions intensity for different percentiles are shown). That there has been a reduction in CO_2 emissions intensity between 2009-10 and 2012-13 is indicated by the graph. The median CO_2 emissions intensity has declined from 2.49 tonnes of CO_2 PMRO to 1.63 tonnes of CO_2PMRO between 2009-10 and 2012-13.

The estimate of kernel density function of the rate of change in CO_2 emissions intensity between 2009-10 and 2012-13 is shown in Figure 6. The rate of change in CO_2 emissions intensity between 2009-10 and 2012-13 has been computed for about 18,000 manufacturing plants which are common between the two surveys. An analysis of the rates of change shows wide variation across plants. There are cases where the CO_2 emissions intensity has declined by more than 90 percent between the two years. On the other hand, there are cases, in which there has been an increase by more than 200 percent. The median is (-)31%., i.e. a fall in CO_2 emissions intensity by 31 percent between 2009-10 and 2012-13, which comes to about 12% annual fall.

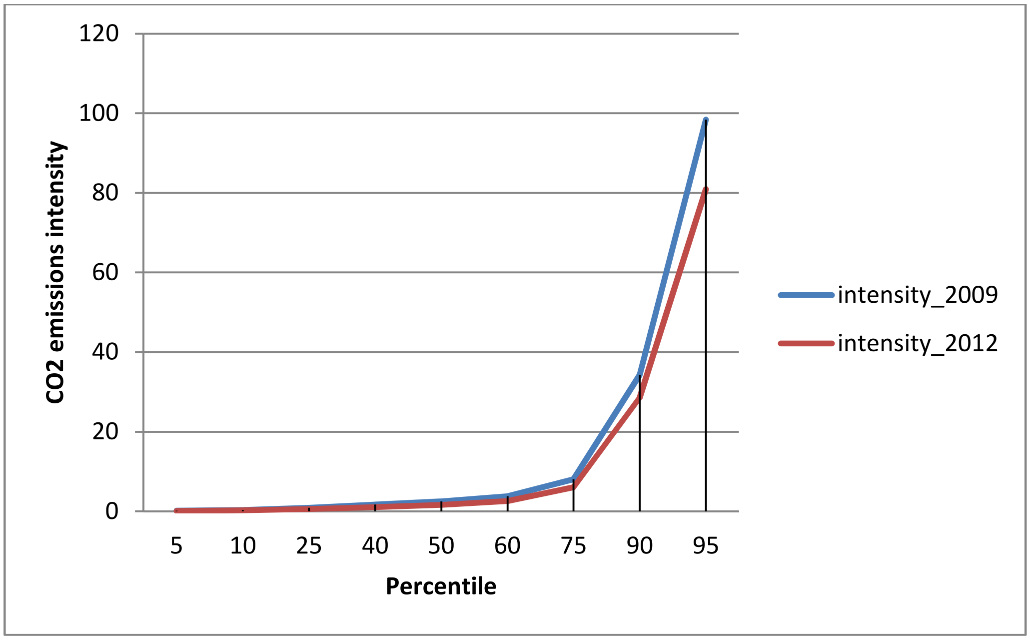

Figure 5: CO_2 emissions intensity (tonnes of CO_2 PMRO), manufacturing plants, percentiles, 2009-10 and 2012-13 (for common plants)

Source: Authors' computation based on unit level ASI data.

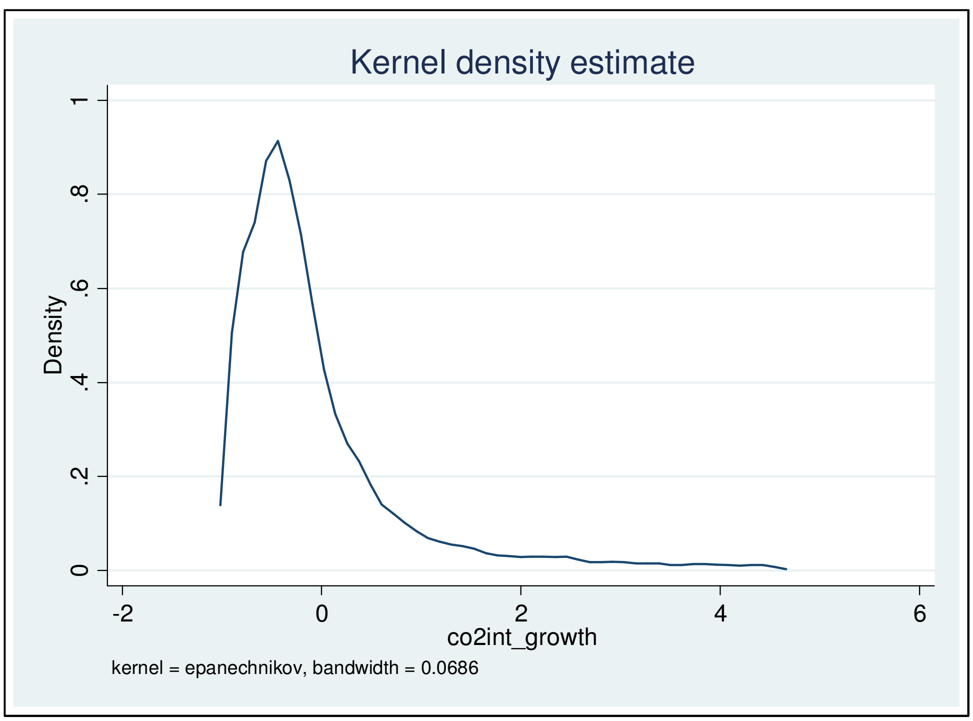

Fig. 6: Kernel density estimate, rate of change in CO_2 emissions intensity between 2009-10 and 2012-13, common manufacturing plants between the two years

Source: Authors' computation based on unit level ASI data.

Attention needs to be drawn to the fact that at the aggregate manufacturing level the rate of fall in CO_2 emissions intensity is only about three percent per annum , but the plant-level data show that the median rate of fall in CO_2 emissions intensity is about 12 percent per annum. The explanation lies, at least partly, in the fact that there are many plants which are large emitters and are experiencing a relatively slow rate of fall in CO_2 emissions intensity (also see Figure 3). Yet, it is remarkable to note that more than half of the Indian manufacturing plants are achieving a rate of fall in CO_2 emissions intensity of over 10% per annum.

3.3 Explaining inter-plant variation in the rate of change in CO_2 emissions intensity between 2009-10 and 2012-13

To explain the wide inter-plant variation in the rate of change in CO_2 emissions intensity, a regression analysis has been carried out. The dependent variable is taken as log difference between the CO_2 emissions intensity in 2012-13 and 2009-10 (which shows the growth rate between the two years). The explanatory variables are by and large the same as in Table 1. Two new variables have been added: whether the plant has an ISO 14000 series certification (in 2009-10) and whether the plant is located in an urban area. The results of the regression analysis are presented in Table 2. The results may be interpreted as follows. Bigger plants have reduced CO_2 emissions intensity relatively more but only if their size is beyond a threshold. Capital intensive plant have achieved a relatively greater reduction in CO_2 emissions intensity. As compared to plants in urban areas, those in rural areas have achieved greater reduction in CO_2 emissions intensity. This is perhaps a reflection of easier availability of power in urban areas than in rural areas. The shortage of power has probably pressurized the plants in rural areas to make efforts at economizing energy use.

An interesting finding emerging from the regression results presented in Table 2 is that after controlling for industry affiliation, size and several other characteristics, the plants with ISO 14000 certification have performed worse than the plants without such certification in terms of reductions made in CO_2 emissions intensity. The coefficient is positive and statistically significant, which means that the plants with ISO 14000 certification have achieved relatively lesser reduction in CO_2 emissions intensity. The reason is not clear. A plant that is environmentally more conscious (and better managed) should have achieved a greater reduction in its carbon emissions intensity. This matter needs further investigation. Perhaps, the plants with ISO 14000 certification in 2009-10 had already reached a good deal of efficiency in energy use and therefore further reduction in energy use was difficult for them. This issue is taken up for additional investigation in the next sub-section.

Table 2: Explaining Change in CO_2 emissions intensity of manufacturing plants, between 2009-10 and 2012-13, Regression Results

Dependent variable: log (CO_2 emissions intensity in 2012-13) – log (CO_2 emissions intensity in 2009-10)

Explanatory variable	Coefficient	t-ratio
Size	0.63	1.99**
Size-squared	-0.0015	-1.68*
Capital intensity	-0.028	-2.29**
ISO 14000 certified (dummy)	0.074	2.51**
Located in urban area (dummy)	0.059	2.51**
New plant (dummy)	0.0038	0.16
Plant belongs to a Private limited company (dummy)	-0.036	-1.24
Plant belongs to a Public limited company (dummy)	-0.036	-1.01
Industry dummies (NIC 5-digit level)	Included (543 categories)	
Constant	-0.72	-2.99***
R-squared	0.05	
F-statistic (Prob.>F)	2.76 (0.005)	
No. of observations	16487	

*,**, *** statistically significant at ten, five and one percent level respectively.

Source: Authors' computation based on unit level ASI data.

3.4 Further investigation of the impact of ISO 14000 certification on CO_2 emissions intensity

Three regression equations have been estimated to probe further the role of ISO 14000 certification. In these models, firm size and a dummy variable for ISO 14000 certification are taken as the only two explanatory variables along with industry fixed effects. The results reported in Table 3.

The coefficient of ISO 14000 certification is found to be negative in both regressions (1) and (2). The sign of the coefficient is as expected, though it is not statistically significant. In regression (3), a dummy variable has been introduced for plants which did not have ISO 14000 certification in 2009-10 but acquired it by 2012-13. For the dummy variable representing such plants, the coefficient in regression (3) is found to be negative and statistically significant. The results indicate that such plants have made a relatively greater reduction in in CO_2 emissions intensity. Taking the estimates of the three regressions together, it seems justified to infer that ISO 14000 certification is associated with improved energy efficiency and environmental performance, culminating in reduction in carbon emissions.

Table 3: Explaining CO_2 emissions intensity of manufacturing plants and its rate of change, 2009-10 and 2012-13, Regression Results

	Regression-1	**Regression-2**	**Regression-3**
Explanatory variable/ dependent variable ⟶	**CO_2 emissions intensity, 2009**	**CO_2 emissions intensity, 2012**	**Log difference in CO_2 emissions intensity between 2009 and 2012**
Size	-2.14 (-5.96)***	-1.11 (-6.47)***	0.039 (2.17)**
Size-squared	0.069 (6.05)***	0.041 (7.02)***	-0.001 (-2.08)**
ISO 14000 certified (dummy), 2009-10	-0.242 (-0.49)		
ISO 14000 certified (dummy), 2012-13		-0.144 (-0.40)	
Plants that did not have ISO 14000 certification in 2009-10 but acquired it by 2012-13 (dummy)			-0.107*** (-2.66)
Industry dummies (NIC 5-digit level)	Included (569 categories)	Included (567 categories)	Included (543 categories)
Constant	31.61 (11.06)***	18.87 (13.99)***	-0.710 (-4.79)***
R-squared	0.48	0.52	0.05
F-statistic (Prob.>F)	12.27 (0.0000)	17.42 (0.0000)	4.03 (0.007)
No. of observations	38639	44011	16746

, * statistically significant at five and one percent level respectively.

Source: Authors' computation based on unit level ASI data.

Figure 7 presents a comparison between plants that newly acquired ISO 14000 certification between 2010-11 and 2012-13 and plants that did not have ISO 14000 certification in 2009-10 and did not acquire it by 2012-13. The comparison is made in respect of reductions achieved in CO_2 emissions intensity. The cumulative distribution of plants according to the rate of growth in CO_2 emissions intensity is shown. The graph indicates that the plants that newly acquired ISO 14000 certification had a relatively greater decline in CO_2 emissions intensity. To do a more rigorous testing, the Kolmogorov-Smirnov test has been applied. The Kolmogorov-Smirnov D-statistic is found to be 0.0589 with a P-value of 0.001. Evidently, a statistically significant difference is found between the two categories of plants. Again, there is empirical evidence to suggest that acquisition of ISO 14000 certification by manufacturing plants is associated with an enhanced rate of fall in carbon emissions intensity.

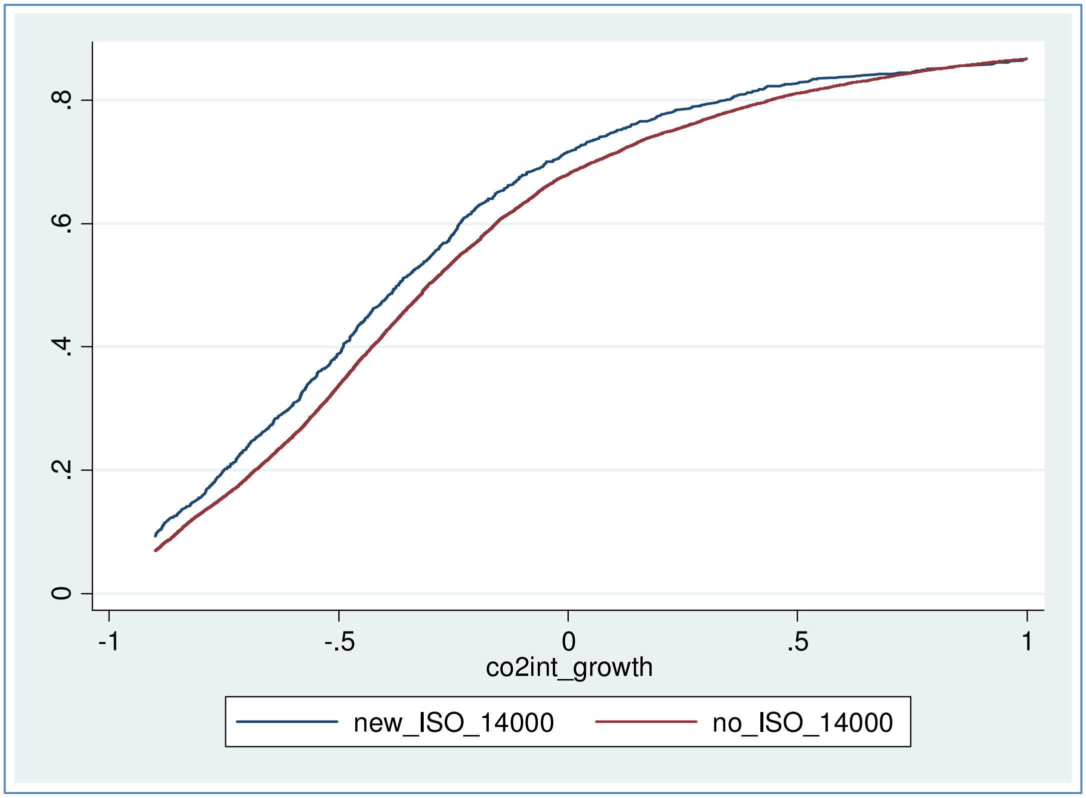

Fig. 7: Cumulative distribution of plants according to the growth rate in CO_2 emissions intensity between 2009-10 and 2012-13, contrasting two categories of plants according to ISO 14000 certification

Note: Plants that newly acquired ISO 14000 certification by 2012-13 are compared with plants that did not acquire ISO 14000 certification.

Source: Authors' computation based on unit level ASI data.

4. Intertemporal Changes in CO_2 Emissions Intensity among Manufacturing Firms

In this section, an analysis of inter-temporal change in CO_2 emissions intensity in manufacturing firms is presented, similar to the plant-level analysis presented in the previous section. A balanced panel of about 4000 manufacturing companies for the years 2009-10 to 2013-14 is used for the analysis. The data have been drawn from the *Ace Equity* database.

The key variable of interest is the CO_2 emissions intensity in various firms. This has been estimated in the following way. Using ASI data, the ratio of CO_2 emissions to expenditure incurred on energy is computed for each three-digit industry. The ratio computed for a particular three-digit industry has been applied to the expenditure on power and fuel reported by the firms (companies) in respect of all companies belonging to that three-digit industry. This provides an estimate of CO_2 emissions of the firm. This is then divided by the sales of the firm to compute CO_2 emissions intensity. Such computations have been made for each three-digit industry for each year, 2009-10 to 2012-13. Since ASI data are not available yet for 2013-14, the ratio mentioned above, computed for 2012-13, has been adjusted for price change between 2012-13 and 2013-14 to derive the ratio for 2013-14, which has then been applied to the figure on power and fuel cost in 2013-14 reported by the firms.

Having obtained CO_2 emissions intensity for different firms for different years, the rate of change between 2009-10 and 2013-14 has been computed which is used as the dependent variable for regression analysis. The median value of the rate of change in CO_2 emissions intensity is found to be -42% which is broadly consistent with the results of the plant level analysis. The Kernel density estimate of the rate of change in CO_2 emissions intensity is presented in Figure 8.

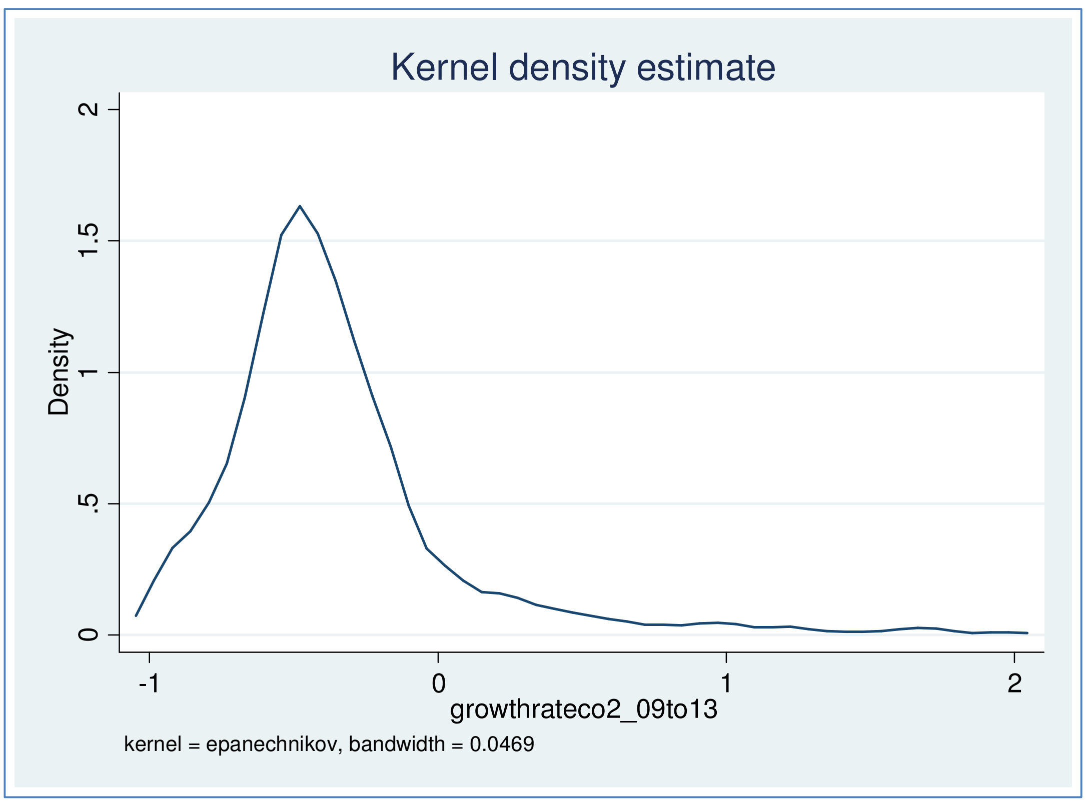

Figure 8: Kernel density estimate, rate of change in CO_2 emissions intensity, 2009-10 to 2013-14

Source: Authors' computation based on Ace Equity data.

A cross-section regression analysis has been undertaken to explain why some firms have achieved a much greater fall in CO_2 emissions intensity than others. The following explanatory variables have been used for the regression analysis: size, capital intensity (ratio of capital stock to labour input), R&D intensity (expenditure on R&D as a ratio to sales), Royalty payment intensity (expenditure on royalty payments to sales ratio), imported materials intensity (value of imported materials divided by sales), and dummy variables for group firms (firms belonging to business groups, e.g. Tata group), MNC firms and public sector firms. The regression results are reported in Table 4.

The results bear some similarities with the results of such analysis done at the plant-level. A negative relationship is found between capital intensity and the rate of change in CO_2 emissions intensity. In other words, the higher the capital intensity of a firm, the larger the fall in CO_2 emissions intensity it achieved during 2008-09 to 2013-14. The coefficient of size variable is negative, which indicates that bigger firms achieved a larger fall in CO_2 emissions intensity.

Table 4: Explaining Change in CO_2 emissions intensity of manufacturing firms, between 2009-10 and 2013-14, Regression Results

Dependent variable: log (CO_2 emissions intensity in 2013-14) – log (CO_2 emissions intensity in 2009-10)

Explanatory variable	**Coefficient**	**t-ratio**
Size	-0.028	-3.25***
Capital intensity	-0.001	-2.04**
R&D intensity	3.86	1.69*
Royalty expenditure intensity	-0.56	-0.20
Imported materials intensity	0.202	2.27**
Group firm	-0.008	-0.18
MNC firm	0.033	0.46
Public sector firm	0.360	2.59***
Industry dummies (NIC 3digit level)	Included (73 categories)	
Constant	-0.44	-10.40***
R-squared	0.115	
F-statistic (Prob.>F)	3.11 (0.002)	
No. of observations	3455	

*,**, *** statistically significant at ten, five and one percent level respectively.

Source: Authors' computation based on *Ace Equity* data.

The regression results indicate that public sector firms have performed relatively worse in terms of reduction in CO_2 emissions intensity. Also, it is found from the results that a firm that has a greater R&D orientation or has a greater dependence on imported materials achieved relatively lower reduction in CO_2 emissions intensity than a similar firm that does not spend on R&D and does not use imported materials.

The relatively poorer performance of public sector manufacturing firms in terms of reduction in carbon emissions intensity will probably not come as a surprise. However, the finding that firms with relatively high R&D orientation and relatively greater dependence on imported materials have achieved a relatively lower reduction in carbon emissions intensity is somewhat unexpected. It is difficult to provide a convincing explanation. Perhaps, the model needs re-estimation with alternate specifications. Thus, no definite conclusion can be drawn on the relationship of these two variables, relating to R&D and imported materials, with reduction in carbon emissions intensity until a more thorough econometric investigation is done.

5. Export Performance and CO_2 emissions intensity, manufacturing firms

How do changes in CO_2 emissions intensity in a manufacturing firm impact its export performance? This is investigated next by estimating an export function for manufacturing firms. Panel data for the years 2009-10 to 2013-14 are used for estimation of the export function. The model is specified as:

$$XI_{jt} = \alpha_j + \beta CI_{jt} + \sum_{k=1}^{m} \gamma_k Z_{jtk} + \varepsilon_{jt} \ldots (1)$$

In the above equation, XI denotes export intensity (ratio of exports to sales), CI denotes CO_2 emissions intensity, and Z denotes other explanatory variables (m variables). The subscript j is for firm and subscript t is for time (year). ε_{jt} is the random error term. The intercept term α_j is allowed to vary across firms to pick up firm specific factors. Since the intercept is allowed to vary across firms, it also picks up inter-industry differences.

The explanatory variable considered for the regression analysis are: (a) firm size measured by the logarithm of fixed assets, (b) labour intensity measured by wages and salary payment as a ratio to fixed capital, (c) dummy for firms which were set up in the post-reform period, (d) ratio imported materials to total materials consumed, and (e) imports to sales ratio.

The model in equation (1) above has first been estimated by the fixed effects model. However, this methodology may be criticized on the ground that the dependent variable is by definition restricted to non-negative values and takes zero value for a substantial proportion of observations. Thus, a Tobit model has an advantage. Given the panel data framework, a panel Tobit model has therefore been applied. The explanatory variables (d) and (e) are similar in nature and correlated. Hence, in some equations, variable (d) has been included, and in others, variable (e) has been included.

It has been noted in the introductory section of the paper that a carbon tax imposed on a firm need not adversely affect its export competitiveness if the regulation induces the firm to be innovative or drives the firm to reduce technical inefficiency. While it is difficult to test this hypothesis in the dataset used for this study, some link between innovation, pollution control and export competitiveness has been brought into the econometric analysis by estimating the export function separately for the firms that have undertaken a positive expenditure on R&D and those who do not incur such expenditure. The former group may be considered as technologically progressive and it would be interesting to find out whether the impact of reduction in CO_2 emissions intensity on export performance differs between the two groups.

The regression results are presented in Table 5. The results indicate that, in general, firm size has a positive effect on export intensity. This, however, does not hold for technology oriented firms. In this case, size does not bear a significant positive relationship with export performance. The findings are similar for labour intensity. It does not have a favourable effect on export performance for technology oriented manufacturing firms, but has a significant positive impact on export performance for other manufacturing firms. The results obtained for the firm-age variable is similar in nature. It appears from the regression results that the export performance is relatively better for firms set up in the post-reform period than those set up earlier, but this relationship does not hold for technology oriented firms.

Another finding clearly emerging from the regression results in Table 5 is that use of imported inputs bears a significant positive relationship with export performance. This is found for the ratio of imported materials to total materials used and also for the ratio of imports to sales.

The coefficient of CO_2 emissions intensity is negative consistently in all equations estimated and statistically significant. This negates the idea that containment of carbon emissions tends to reduce export competitiveness of firms. Rather the opposite is indicated, as found by Costantini and Mazzanti (2012) for EU firms. It may be noted further that a significant negative coefficient of CO_2 emissions intensity is found for technology oriented firms and also for other firms. The numerical value of the coefficient is similar in the two cases.

Table 5: Explaining Export Performance of manufacturing firms, 2008-9 and 2013-14, Regression Results

Dependent variable: export intensity (export to sales ratio)

Explanatory variable	**Regressions**						
	(1)	(2)	(3)	(4)	(5) Firms with +ve R&D	(6) Firms with +ve R&D	(7) Firms without R&D expenditure
CO_2 emissions intensity	-0.002 (-1.64)*	-0.003 (-2.54)**	-0.009 (-3.53)***	-0.013 (-4.93)***	-0.011 (-4.66)***	-0.009 (-3.66)***	-0.014 (-3.29)***
Size	0.016 (5.28)***	0.017 (5.91)***	0.076 (25.8)***	0.080 (27.6)***	0.005 (1.32)	0.003 (0.9)	0.076 (15.78)***
Labour intensity					-0.096 (-1.71)*	-0.080 (-1.44)	0.123 (2.20)**
Imported materials intensity	0.0018 (3.19)***		0.046 (12.77)***			0.013 (7.40)***	0.217 (16.14)***
Imports/Sales		0.022 (11.09)***		0.046 (11.45)***	0.018 (9.25)***		
Firm set up after 1991			0.40 (3.21)***	0.40 (3.13)***	0.002 (0.01)	0.007 (0.04)	0.626 (2.73)***
Constant	0.029 (2.08)**	0.022 (1.72)*	-0.89 (-7.15)***	-0.92 (-7.2)***	0.168 (0.8)	0.169 (0.8)	-1.32 (-5.72)***
Method	Fixed effects	Fixed effects	Panel Tobit	Panel Tobit	Panel Tobit	Panel Tobit	Panel Tobit
R-squared	0.029	0.039					
Log-likelihood			-3054.4	-3187.6	2884.6	2930.0	-3209.5
Wald Chi-sqr (Prob.>Chi-sqr)			900.8 (0.000)	962.4 (0.000)	122.7 (0.000)	71.7 (0.000)	553.2 (0.000)
F-statistic (Prob.>F)	15.27 (0.000)	57.66 (0.000)					
No. of observations	18778	19507	18778	19507	5355	5329	13449

*,**, *** statistically significant at ten, five and one percent level respectively. Source: Authors' computation based on Ace Equity data.

6. Conclusion

Some of the important findings of this study are: (a) in the last 10 to 15 years, Indian manufacturing has reduced CO_2 emissions intensity at the rate of 3 to 3.5 percent per annum and if this trend continues then the reduction in CO_2 emissions intensity made by Indian manufacturing in the period 2005 to 2030 will exceed the national level target for 2030 announced by the Indian government recently, (b) a majority of manufacturing plants have achieved, in recent years, a reduction in CO_2 emissions intensity at the rate of 10 percent per year or more, (c) large firms and capital intensive firms have achieved a relatively faster decline in CO_2 emissions intensity, (d) acquiring of ISO 14000 certification has been associated with enhanced fall in CO_2 emissions intensity, and (e) reduction in CO_2 emissions intensity does not adversely impact export performance – rather the econometric results indicate that reductions in CO_2 emissions intensity go hand in hand with increased export intensity.

The Indian government introduced in 2012 a market based instrument for improving energy use efficiency in industrial plants in the form of the PAT (perform, achieve, trade) scheme. The target in the first phase was set at 4% saving in energy use over a period of three years. Given the reductions in energy intensity that Indian manufacturing plants have actually made in the recent years on their own, the target of PAT scheme appears small. There is need to review the target in the next phase of three years.

In order to ensure that the past downward trend in CO_2 emissions intensity in Indian manufacturing continues in the coming years so as to meet the national level target for the reduction in CO_2 emissions intensity set by the Indian government recently for the year 2030, it may be necessary to make use of a carbon tax or a market based instrument for emissions control. One may fear that such a move would cause a loss of export competitiveness of Indian manufacturing firms. The analysis presented in Goldar and Bhalla (2015) indicates that even if a reasonable carbon tax imposed on Indian manufacturing firms gets translated into a cost hike, the adverse effect on manufacturing firms' exports is likely to be small. The econometric analysis presented in this paper builds further a case for the use of economic instruments for containment of CO_2 emissions in Indian manufacturing by showing that in the past reductions in CO_2 emissions intensity in manufacturing firms have not been associated with any drops in export performance. Rather, containment of CO_2 emissions seems to have contributed to better export performance.

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