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EU-CBAM and India's Firm-level Carbon Emissions:
Sustainability and Environmental Concerns

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The European Union (EU) has notified the World Trade Organisation (WTO) about its national measure, which is also a strategic intention to institute a comprehensive 'Carbon Border Adjustment Mechanism' to address the "green-house-gases" (GHGs) emission and the related "climate-change" challenges. The EU regulation known as CBAM has the potential for heralding a pivotal moment in international trade regulation. The EU's proposed framework targets eight industries with substantial energy demands, including iron and steel, aluminium, cement, electricity, fertilizer, and hydrogen. Notably, the potential implications of carbon taxation resonate distinctly within the Indian economic landscape, with specific sectors like iron, steel, and aluminium standing out due to their pronounced export orientation. This paper aims to compute carbon emission intensity across firms belonging to two sectors, namely iron, steel, and aluminium, for the period 2000 to 2022 and understand its relationship with investment in plant and machinery for these sectors. The preliminary finding suggests a decline in firms' average carbon emission intensity across both industries, as they declined during the study period. A negative and significant relationship exists between investment in plant and machinery and carbon emission intensity in these sectors.

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Abstract

The quality of corporate governance is broadly a function of the domestic legislative architecture; in the present world with GVCs linkages, it is also the function of the international legislative regime. In other words, it is a function of the dominant market with the growing demand. There has been a delta calling for a radical shift from efficiency and competitiveness to effectiveness in production. All future projects in countries exporting to the EU market would be governed by the CBAM directives (regulations). The quality of governance during the liberalisation period in India (1991 to 2019) and later is primarily linked to the SDGs and the related nationally determined commitments (NDCs) and, secondly, to the COVID-19 pandemic.

The CBAM regulation would require importers of certain energy-intensive goods to pay a levy for their imports corresponding to the emissions allowances price under the EU-Emissions Trading System ("EU-ETS"). Thus, the EU's NDCs are forced upon its trading partners who would want to be the exporters; therefore, it introduces a green production process like that adopted in the EU - as part of its NDCs for meeting the SDGs of net zero carbon target by 2050. The Indian firms operating in sectors like iron, steel, and aluminium would need to adopt such legislative-driven changes in the production process of their exports to the EU.

The European Union (EU) has notified the World Trade Organisation (WTO) about its national measure, which is also a strategic intention to institute a comprehensive 'Carbon Border Adjustment Mechanism' to address the "green-house-gasses" (GHGs) emission and the related "climate-change" challenges. The mechanism is so designed to address the challenges posed by carbon emissions. Therefore, it can potentially target the energy-intensive sectors at the primary and secondary levels. The EU regulation known as CBAM has the potential for heralding a pivotal moment in international trade regulation. The EU's proposed framework targets eight industries with substantial energy demands, including iron and steel, aluminium, cement, electricity, fertilizer, and hydrogen. Notably, the potential implications of carbon taxation resonate distinctly within the Indian economic landscape, with specific sectors like iron, steel, and aluminium standing out due to their pronounced export orientation.

This paper aims to compute carbon emission intensity across firms belonging to two sectors, namely iron, steel, and aluminium, for the period 2000 to 2022 and understand its relationship with investment in plant and machinery for these sectors. The preliminary finding suggests a decline in firms' average carbon emission intensity across both industries, as they declined during the study period. A negative and significant relationship exists between investment in plant and machinery and carbon emission intensity in these sectors.

Keywords: CBAM, Carbon Emission, energy-intensive sectors, European Union, WTO

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EU-CBAM and India's Firm-level Carbon Emissions
Sustainability and Environment Concerns

1. Introduction

The European Union (EU) has recently taken a significant step by formally notifying the World Trade Organization (WTO) of its intention to establish a 'Carbon Adjustment Mechanism.' This mechanism aims to address the issue of carbon leakage, which arises when firms relocate their production outside the EU to countries with relatively less stringent application of environmental regulations. The proposed mechanism involves imposing a carbon tax on greenhouse gas emissions embedded in imports to prevent such leakage. The EU's plan initially focuses on eight energy-intensive industries: iron and steel, aluminium, electricity, fertilizer, and hydrogen. This proposed carbon tax is anticipated to affect exports from developing countries to the EU adversely. Firms in developing nations might have emission standards lower than those in the EU, leading to decreased international competitiveness. Moreover, since the implementation of the EU Emission Trading System (ETS) in 2005, energy-intensive firms have been granted ample time to transition towards greener production processes.

> *Greenhouse gas (GHG) emissions from anthropogenic factors/ economic activities are attributed to be the most significant factor leading to climate change. GHGs primarily comprise six gases: water vapour (H2O), carbon dioxide (CO2), nitrous dioxide (N2O), Methane (CH4), Sulphur hexafluoride (SF6), and Hydrocarbons (PFCs & HCFCs).*[2]

As a result, the imposition of carbon taxes has the potential to hinder exports from firms located in developing nations. Past literature suggests that the ramifications of the potential carbon taxes on India are particularly pronounced in sectors such as iron, steel, and aluminium, given that these industries hold greater significance due to their present status in export orientation in contrast to commodities like cement, electricity, fertilizer, and hydrogen.

As the regulation would impact the exports and their orientation and the states do not control almost all of the exports, and it is the firms that indulge in the activity – it would be appropriate to understand the exportable capacity of the entity under the revised policy framework. The variability in carbon emissions within a given industry is closely linked to the diverse production techniques adopted by individual firms. An illustrative example from the steel sector can be drawn, a primary focus within the Carbon Border Adjustment Mechanism (CBAM). Steel production methods encompass several distinct approaches, including the Blast Furnace/Basic Oxygen Furnace (BF-BOF) that predominantly employs coal or coke as raw materials, Induction Furnaces (IF), and Electric-arc Furnaces (EAF) which rely on Direct Reduced Iron (DRI) or steel

[2] E&Y, 2018, Discussion Paper on Carbon Tax Structure for India, published jointly by Ernst & Young LLP and Shakti Sustainable Energy Foundation, Published in India by Ernst & Young LLP.

scrap as input. Notably, the carbon emissions associated with steel manufacturing differ significantly among these methods, with BF-BOF and IF techniques emitting a greater carbon volume than the EAF approach. In the context of the landscape of India's steel production, according to the annual report of the Ministry of Steel in 2022-23, approximately 46 percent of total crude steel is produced through the BF-BOF method, followed by 31 percent from Induction furnaces, and 23 percent from Electric arc furnaces.[3] As electricity is exempted for the present from the CBAM regulation, we could conclude that only 23 percent of steel products would be exempt from the EU-CBAM regulation.

In the Indian context, several empirical studies shed light on the dynamics of energy and carbon emissions within the manufacturing sector. Goldar (2012) examined data spanning 1992 to 2009, revealing a substantial 60 percent reduction in energy intensity among Indian manufacturing firms. Similarly, Sahu and Narayan (2011) observed a significant 25 percent decline in average carbon emission intensity from 2000 to 2008. Expanding on this, Sahu and Narayan (2013) conducted a detailed analysis at the firm level, identifying factors contributing to inter-firm variability in emissions. In a subsequent study, Goldar and Bhalla (2015) explored the potential impact of carbon emission reductions on export competitiveness, utilizing data from 2007-08 and demonstrating the feasibility of emissions reduction through factor substitution. However, Goldar et al. (2017) reported a counterintuitive finding of a positive correlation between decreased emission intensity and export competitiveness, revealing a 12 percent reduction in carbon emission intensity within the Indian organized manufacturing sector from 2009-12.

Therefore, this research endeavour is centred upon the computation of carbon emission intensity within the iron & steel, and aluminium industries at the firm level, thereby delineating the influence of their energy sources. Moreover, to understand the relationship between investment in plant and machinery and carbon emission intensity in these sectors. This would have two potential impacts in the context of the EU-CBAM, one in terms of direct costs of upgrading the technology and the other the price impact as a direct consequence of the taxes imposed at the border. Thereby making a case for how much investment the Indian steel and aluminium sectors have undertaken to achieve break-even in exportable gains. This, however, would also depend on India's share of total imports in the EU. The temporal scope encompasses the period spanning from 2000 to 2022.

Our finding from the investigation notably reveals a progressive decline in the carbon emission intensity as exhibited by firms over the stipulated timeframe. This reduction in emission intensity can be primarily attributed to a progressive shift towards embracing renewable energy sources, notably solar and wind power, by various firms operating within these sectors. We also find a negative and significant relationship between investment in plant and machinery and the carbon

[3] Ministry of Steel, Annual Report 2022-23, Government of India, Page 17, https://steel.gov.in/sites/default/files/MoS%20AR%202022-23.pdf.

emission intensity of these sectors, highlighting that investment in plant and machinery will be required to decrease carbon emission intensity to remain competitive.

Within this context, the structure of the paper is organised as follows: Section 2 entails a literature review, providing a comprehensive backdrop to the study's theoretical and empirical underpinnings. Subsequently, section 3 expounds upon the methodology employed. Section 4 presents the empirical findings on the observed trends and patterns in carbon emission intensity. Section 5 summarises the essential findings and outcomes, offers insights into the implications for Indian policymakers, and provides a basis for future avenues for further research in the area.

2. Literature Review

Many studies collectively explain the intricate dynamics of emissions reduction, export competitiveness, and production outcomes within the context of manufacturing firms. A considerable volume of scholarly literature suggests that a well-structured environmental regulation aimed at improving the ecological performance of an industrial enterprise does not necessarily result in a decline in its competitive standing; instead, it has the potential to bolster it. This perspective, recognised as the Porter hypothesis i.e., strict environment policy can improve competitiveness. It can lead to better environmental outcomes, as originating from research conducted by Porter et al. (1995). This perspective also garners empirical substantiation, exemplified by studies such as those undertaken by Lanoie et al. (2008), Leeuwen et al. (2013), and Rubashkina et al. (2015). The rationale behind the positive influence of environmental regulations on the competitive stance of firms resides in the impetus these regulations provide for innovation, subsequently enhancing firm productivity and, consequently, its competitive edge. A notable study by Costantini et al. (2012) analysed the impact of an environmental tax on the export performance of firms in the EU. They found a positive effect of carbon taxes on the export of high and medium technology sectors. The authors suggest that energy and environmental taxes help high-tech companies by encouraging new technology and innovation. However, for medium- to low-tech companies, these taxes are helpful because they allow them to use energy more efficiently, which makes them more competitive.

In the Indian context, Goldar (2012) conducted an empirical investigation from 1992 to 2009, revealing a substantial reduction of 60 percent in the energy intensity of manufacturing firms within India. Likewise, Sahu et al. (2011) observed a noteworthy decline of 25 percent in the average carbon emission intensity among Indian manufacturing firms from 2000 to 2008. Building on this, Sahu et al. (2013) undertook a comprehensive analysis, estimating carbon emissions at the firm level and identifying factors contributing to the inter-firm variability in emissions.

In a subsequent study, Goldar et al. (2015) delved into the potential implications of carbon emission reductions on the export competitiveness of Indian manufacturing firms. Using data from 2007-08, they employed a production function framework and demonstrated the feasibility of substantial emissions reduction through factor substitution. Their findings indicated a projected decline in exports by 0.33-1.36 percent in response to an increase in carbon tax ranging from 4 to 15 per tonne. In contrast, Goldar et al. (2017) reported a 12 percent reduction in carbon emission intensity within the Indian organized manufacturing sector during 2009-12, revealing a counterintuitive finding of a positive correlation between the decrease in emission intensity and export competitiveness. Additionally, Bagchi et al. (2022) contributed to the discourse by conducting a firm-level analysis, elucidating the intricate trade-off between carbon emissions and firm output.

Many studies, spanning industrialized nations and emerging economies, have consistently indicated that involvement in export activities among industrial enterprises correlates with reduced energy intensity and CO2 emissions intensity. This trend is further echoed in analogous studies conducted on Indian manufacturing firms, utilizing firm-level data, which converge on the same conclusion. For instance, in their research, Goldar et al. (2023) leverage plant-level data from 2008 to 2015 to explore the influence of export intensity on the energy intensity of Indian manufacturing. Employing plant-level data offers a distinct advantage by capturing location-specific nuances, such as utilizing renewable energy sources like solar and wind within each plant's state. Their analysis reveals a noteworthy negative correlation between export and energy intensity, echoing previous research findings. Moreover, they observe that the energy efficiency gains associated with exporting are more pronounced in industries with higher energy consumption than their counterparts. Additionally, the study underscores the role of renewable energy sources in enhancing industrial energy efficiency, highlighting the potential for further improvements in sustainability within the manufacturing sector.

However, even the opposite has been confirmed, where certification to environment management systems such as ISO 14000 has increased export intensity. For instance, Goldar (2023) conducted an econometric analysis using plant-level data from the Annual Survey of Industries to explore the impact of ICT. Investment and ISO 14000 certification adoption on the export performance of Indian manufacturing plants. Covering the period 2008–09 to 2017–18, the study includes approximately 150 thousand plants and 440 thousand observations. Results indicate a significant positive effect of ICT investment and ISO 14000 certification on export intensity. Factors such as outsourcing manufacturing activity, the share of imported materials, and higher contract worker intensity are associated with improved export performance, particularly in low-technology industries.

In India's context, the following literature gaps were identified. There need to be studies explicitly addressing the calculation of carbon emission intensity among energy-intensive firms. Existing research predominantly concentrates on the manufacturing sector as a whole. Furthermore, there has been an improvement in the quality of firm-level data over time, resulting in a more significant number of firms and more comprehensive information on the energy sources utilized by each firm. Finally, an unexplored aspect of the relationship between investment in plant and machinery and its impact on carbon emissions remains, which is the primary focus of our paper.

3. Data Sources and Methodology

This paper has undertaken the following methodology to estimate the CO2 emissions and CO2 emissions intensity (ratio of aggregate carbon emissions to volume) at the firm level of specific industries.

Identification of Firms

Firstly, using CMIE Prowess IQ, we have extracted a list of all firms in the Metal and Metal Products Category, which includes ferrous metals such as iron and non-ferrous metals such as aluminium. At the preliminary level, 2,298 companies fall in this category. For each of these companies, we have extracted energy consumption data for the period 2000-2022.

Further, each firm in the listed dataset has been mapped to the national industrial classification (NIC) code. The NIC code is an essential statistical standard for developing and maintaining a comparable database according to economic activities, updated by the Central Statistical Organisation (CSO). The NIC codes were assigned to all the firms in our dataset, and NIC primarily falls into the divisions: Manufacture of essential metals; Manufacture of fabricated metal products, except machinery and equipment; Manufacture of machinery and equipment not elsewhere classified (n.e.c.,); Other manufacturing; and Repair and installation of machinery and equipment were of primary interest. The NIC interest codes at four digits were 2410, 2431, 2420, 3311, 2511, 2512, 2599, 2817, and 3290. The firms with NIC codes other than those mentioned above were omitted from the analysis, bringing down the number of firms to 960. Additionally, we further marked each firm's sector code against NIC codes.

The Calculation of CO_2 Emission Intensity

Estimating the intensity of CO2 emissions at the firm level involves five steps. Firstly, a company's greenhouse gas emissions (carbon dioxide) are distributed across various energy source categories a firm utilises; hence, the first task was to harmonise the different energy sources into specific standard energy sources across all firms. This helped comparably standardise the results. Post bringing homogeneity to the energy sources, the primary energy sources part of the analysis are - Electricity, Diesel, Furnace oil, Coal, LPG, Wind Mills, Wood, Water, Solar energy, and Others. Each firm reported data on the quantity consumed in various units in each energy source. Hence, for comparison, the units were standardised. Additionally, based on our understanding of the other energy source, we have further divided the energy source based on units reported in nine of the above categories. However, we have dropped specific observations such as those with units- Cylinders, Numbers, Terms, and the TBTU.[4]. In total 40 such observations were dropped, of which 9 were TBTU observations.

The second step in the analysis was to identify the accurate Net Calorific Value (NCV)[5] and Emission Factors (EF).[6] The firm uses each energy source to calculate the carbon emission at the firm level. In this paper, the NCVs and EFs prepared by the Indian Network for Climate Change Assessment (INCCA) has been utilised. Further, the estimates were made using revised IPCC 1996 guidelines (1997), IPCC Good Practice Guidance (2000), and the LULUCF Good Practice Guidance (2003). The EFs were also a mix of default present in IPCC publications (1997, 2000, 2003, and 2006) and Country Specific (CS) but were of improved accuracy as a more significant number of CSs have been used in this assessment (35% of the source categories used CS factors). A simple representation of the methodology used in this paper for estimating carbon emission from each energy source category is shown in the following formula:

$$CO_2 = QV * EF * NCV$$

Where- QV is the quantity consumed by each energy source.

Table 1: Choice of NCV and CO2 EFs of different types of fuel used for estimation

Energy Source	NCV (Tj/kt)	Emission Factor (t/Tj)
Coal	23.66	25.55
Diesel	43.00	74.10
Oil	40.00	77.00
LPG	47.30	63.10
Wood	47.30	63.10

Source: "India: Greenhouse Gas Emissions 2007", Indian Network for Climate Change Assessment, Ministry of Environment and Forests, GoI 2007; Tj – Terajoule; kt- Kiloton; t- Tonne

Table 1 above accentuates the NCVs and EFs used in the analysis. Carbon emissions were assumed to be zero for renewable energy sources such as solar, wind, and water. The emission factors of fossil fuels such as coal, oil, and natural gas are the most critical considerations when estimating the GHG emissions from the combustion of these fuels. In India, coal as a fuel constitutes more than 50% of the total fossil fuel mix of the country used for energy-related activities. We have taken a few more steps before the final assessment to obtain CO2 emissions intensity (ratio of aggregate carbon emissions to volume) at the firm level.

The third step entailed extracting consolidated and standalone sales for each firm each year from the CMIE ProwessIQ database. Wherever consolidated sales were null, they were replaced by

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[4] TBTU means **trillion BTU (British thermal unit)** a unit of measurement for energy.

[5] Net Calorific Value (Net CV) is **the practical amount of energy which may be realised at atmospheric (constant) pressure**. This is the most practically meaningful value that is expressed on an 'as received basis' (i.e. including the moisture content), since that is typically how the fuel will be burned.

[6] Definition. An emission factor is a coefficient which allows to convert activity data into GHG emissions. It is the average emission rate of a given source, relative to units of activity or process/processes. For example: the natural gas emits 0.244 kg CO2eq / kWh ICV (European mean) with 5% uncertainty.

standalone sales, and in other cases where consolidated sales were present, that value was taken. This method prevents any bias and error due to double counting.

The fourth step was to extract prices NIC code-wise from the Annual Survey of Industries (ASI) from 2000-2022. Part 1 of the Annual Survey of Industries (ASI) schedule was structured in 14 blocks. It is the central part of the schedule and is meant to collect economic and related categorical data for the selected unit. In the ASI, block 1, Block A, had unique identification codes. The desired economic variables (sales and quantity) existed in Block J. Hence, the five-digit NIC code in Block A was mapped in Block J, which had the desired variables to calculate the prices. Using the Despatch Serial Number (DSL) number, which is unique across the country for a particular year of survey, the NIC code was mapped from Block A to Block J. Next, in Block J, only those units which were in 'tonne' were kept part of the analysis and other units were dropped. After which, we kept only those values of quantity sold that were not zero. Finally, gross sale value was divided by the amount sold to obtain prices at the industry level. Lastly, average prices NIC-wise and year-wise were found.

Since the ASI has not been released for the years 2021 and 2022, for calculating the average price of 2021 and 2022, we have utilized the Annual Average of Monthly Index (Financial Year 2012-13 Onwards), which has 2011-12 =100 as the base. We multiplied 2011-12 prices by the index value of 2020-2021 & 2021-2022 to get the average prices for the recent years.

We would also like to point out that during the period taken for the analysis, 2000-2022, the NIC codes were revised thrice (NIC-1998, NIC-2004, and NIC-2008). We have considered these and mapped NIC-1998 and NIC-2004 to NIC-2008 using concordance tables to obtain accurate average price data.

The fifth step entailed using the average price data at the industry and firm levels. In this step, for each firm falling in an industry (identified by NIC code), we get the volume of firms by dividing the sales by the average price, which was in (Rs/Tonnes) as identified in the fourth step. Finally, we aggregated each firm's emissions from all energy sources to obtain average emission intensity. In other words, emission intensity is defined as aggregated emission divided by volume. Thus, a standardized data set for applying econometric exercises was created to analyze energy-intensive sectors like Iron & Steel and Aluminum.

4. Econometric model

In this study, we employ a model inspired by the work of Sahu and Narayan (2014), who examined the carbon emission intensity of firms about various firm-level characteristics. Our adaptation of their model focuses on elucidating the intricate relationship between a firm's investment in plant and machinery and its carbon emission intensity while controlling for factors such as size, experience, and capital intensity.

The dependent variable in our analysis is carbon emission intensity, denoted in Equation 1. It is computed by dividing a firm's total emissions by its output volume. To mitigate skewness and enhance the interpretability of coefficients, we employ a log-log model, wherein both the dependent and independent variables are logarithmically transformed.

$$
\begin{aligned}
Log(Carbon\ emission\ intensity)_{i,t} = \\
&\propto + \beta_1 Log(Investment\ in\ Plant\ and\ Machinery)_{i,t} \\
&+ \beta_2 log(Capital\ intensity)_{i,t} + \beta_3 log(Sales)_{i,t} + \beta_4 log(Age)_{i,t} \\
&+ \beta_5 Log(Investment\ in\ Plant\ and\ Machinery)_{i,t} * Sector\ dummy \\
&+ \beta_6 Log(Investment\ in\ Plant\ and\ Machinery)_{i,t} * Exporter\ dummy + \mu_i + \delta_t \\
&+ \varepsilon_{i,s,t} - (1)
\end{aligned}
$$

Consider the gross plant and machinery value in a given year to indicate a firm's investment in plant and machinery. This variable encapsulates the monetary value of a firm's plant and machinery at its purchase price. Our hypothesis posits that firms with higher investments in plant and machinery are likely to exhibit lower carbon emission intensity, reflecting a potential positive relationship between environmental efficiency and investment expenditure.

Furthermore, we integrate the logarithm of total sales as an indicator of firm size. Given the scale of their operations, larger firms are anticipated to have higher carbon emission intensity. Concurrently, we gauge a firm's experience by employing its age since incorporation. The underlying assumption is that older firms may display higher carbon emission intensity, reflecting historical practices and technological obsolescence.

Incorporating capital intensity as an additional indicator, we utilize the ratio of gross fixed assets to sales. Firms with higher capital intensity are expected to have lower carbon emission intensity, aligning with the notion that increased capital investments may result in adopting cleaner and more sustainable technologies.

In equation 1, we introduce two dummy variables, the exporter dummy and sector dummy, to examine potential variations in the relationship between investment in plant and machinery and carbon emission intensity. The exporter dummy assumes a value of 1 if a firm's exports are more significant than 0 in a given year. Our hypothesis posits that firms engaged in exporting may exhibit a more pronounced correlation between investment and emission intensity. On the other hand, the sector dummy takes on a value of 1 for firms operating in the aluminium sector and 0 for those in the iron and steel industry. This distinction enables us to explore whether the relationship between investment and emission intensity differs across various sectors.

In our analysis, we conducted six regression models. In the first regression, we regressed the log of investment in plant and machinery solely on carbon emission intensity. The second regression introduced an additional independent variable, the log of capital intensity. For the third regression, we added a third independent variable, the log of sales. The fourth regression incorporated all the previous independent variables and included the firm's age as an additional independent variable. The fifth regression model included an interaction term between the log of investment in plant and machinery and the sector dummy variable. Lastly, the sixth regression model added an interaction term between the log of investment in plant and machinery and the exporter dummy variable.

We introduce firm and time-fixed effects into our model to account for unobserved heterogeneity. These fixed effects capture the unobservable characteristics inherent to individual firms and the temporal dynamics influencing carbon emission intensity. Considering these factors, our study aims to contribute insights into the complex interplay between investment in plant and machinery and firm carbon emission intensity.

5. Descriptive Analysis

Over multiple years, this section delved into the carbon emission and emission intensity trends in the energy-intensive industries (the iron, steel, and aluminum sectors). Data from all energy sources, excluding electricity, were analyzed to gauge a firm's carbon emissions accurately. Interestingly, the comparison between these two sectors revealed nuanced differences.

Within the iron and steel sector, comprising 526 firms, a discernible pattern emerged from 2000 to 2008. The emissions trajectory began with approximately 29 million tonnes of CO2 in 2000, steadily escalating. The peak in emissions was reached in 2008, surpassing a staggering 1 million tonnes of CO_2, indicating a remarkable 41-fold surge since the early 2000s. This is in line with the extraordinary growth in GDP experienced during the period. During 2003-08, Indian GDP grew annually on average at 7.1%[7]. Post-2008, emissions disembarked downward, with occasional upticks in 2010, 2014, 2018, and 2022. After the financial crisis of 2008, Indian GDP growth also slowed down during specific years, coinciding with the downward emissions trend. For example, during 2011 and 2012, GDP grew annually on average at 5.35%, much lower than in previous years. As shown in Figure 1, the emissions declined by approximately 50% and 22% during the same period, respectively. Similarly, we find that in 2017 and 2019, emissions fell by 12% and 80%, and GDP grew at a much slower pace of 6.8% and 3.9%, which was approximately 18% and 40% lower than previous years.[8]

The mirror trends in both reiterate that '*the growth of many economies has been largely shaped by the strength of their steel industries in their initial stages of development.*' India's growth journey is interwoven with the country's leveraging the potential of the mining and manufacturing industry to its fullest, particularly iron and steel, a core sector. Due to both

7 https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/IND?zoom=IND&highlight=IND
8 Ibid.

backward and forward linkages, the iron and steel sector's growth is positively related to economic activity in the country and its demand at the global level.[9]

In contrast, housing a mere 62 firms, the aluminum industry exhibited a more volatile emissions landscape. Peaking at 55 million tonnes of CO_2 emission in 2001, there was a subsequent dip to 50 million tonnes of CO_2 emission in 2002, followed by relatively subdued emissions in 2003 and 2004. Another crest of emissions emerged in 2008 (approximately 22 million tonnes of CO_2 emission), with a notable 25% annual growth rate since 2007. The aluminum industry also witnessed heightened emissions in 2013 and 2014 (approximately 4 million tonnes of CO2 annually), gradually tapering off to less than 1 million tonnes of CO2 annually from 2020 onwards, partly attributable to data availability constraints. It was found that from 2020 onwards, data on only 11 or fewer firms were available.

Upon review of the data, there could be two reasons for such varied trends in emissions in the energy intensity sectors. Firstly, we excluded electricity from our analysis, as the EU-CBAM exempted it.[10]. If electricity is included, emissions from the aluminum sector would be at par with the iron and steel industry or may even exceed the latter in specific years. Secondly, as pointed out earlier, the number of firms comprising each energy intensity sector is the opposite. The iron and steel industry from 2000-2022 includes more than 525 firms, whereas the aluminum sector only has 65 firms during the same period. Due to the small number of firms comprising aluminum, the industry is prone to sudden changes in emission since each year, the number of firms varies and is a significant driver of sudden changes in emission. Figure 10 in the annexure elucidates the annual number of firms in both sectors. The maximum number of firms in a year was 307 for the iron and steel sector in 2010. However, this number, as seen from the figure, varied annually. On the other hand, the maximum number of firms in a year was 34 for the aluminum sector in 2011.

Despite the divergent levels of carbon emissions, we find that both sectors experienced heightened emissions compared to previous years in certain common years, such as 2008, 2014, and 2018. Moreover, as of 2022, emissions in both industries have receded compared to levels observed two decades prior, indicating a discernible paradigm shift in emission dynamics over time.

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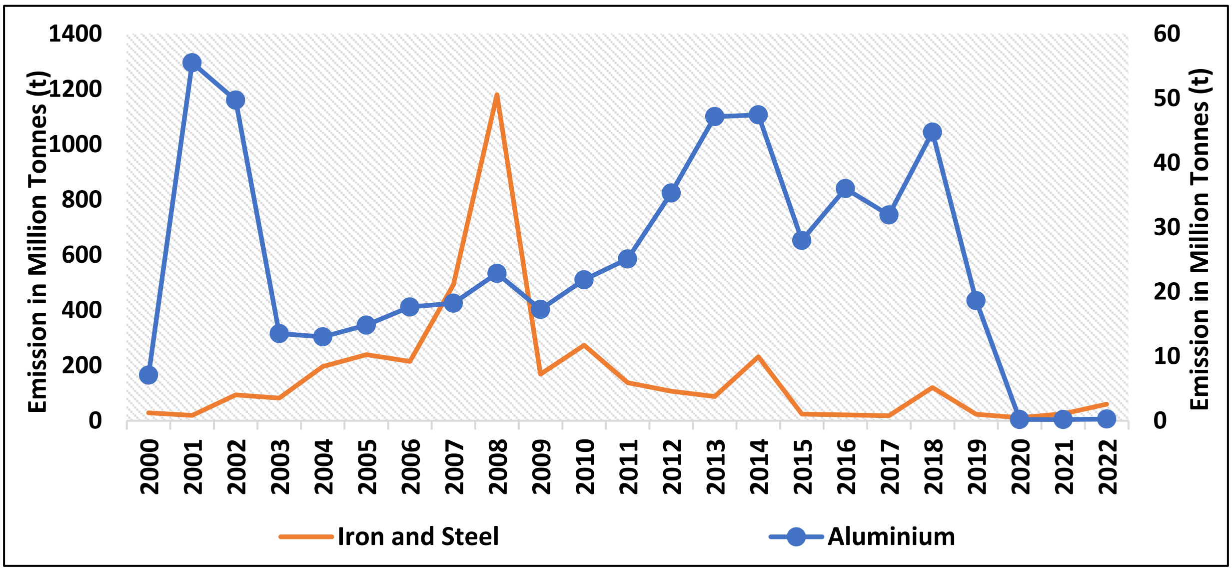
9 https://etinsights.et-edge.com/indias-iron-steel-sector-a-key-driver-to-fulfil-the-vision-of-5-trillion-economy/, https://steel.gov.in/sites/default/files/Chapter%20II%20%281%29.pdf, https://infra.economictimes.indiatimes.com/news/construction/steel-sector-growth-vital-for-massive-investments-in-infra-piyush-goyal/105038997, and https://www.cci.gov.in/public/images/marketstudie/en/docs1652438794.pdf.

10 The CBAM applies to electricity generated in and imported from third countries including those that wish to integrate their electricity markets with the EU. If those electricity markets are fully integrated and provided that certain strict obligations and commitments are implemented, the concerned countries could be exempted from the CBAM. If that is the case, the EU will review any exemptions in 2030, at which point those partners should have put in place the decarbonisation measures they have committed to, and an emissions trading system equivalent to the EU's.

Figure 1: Carbon emission in the aluminum and iron & steel industry



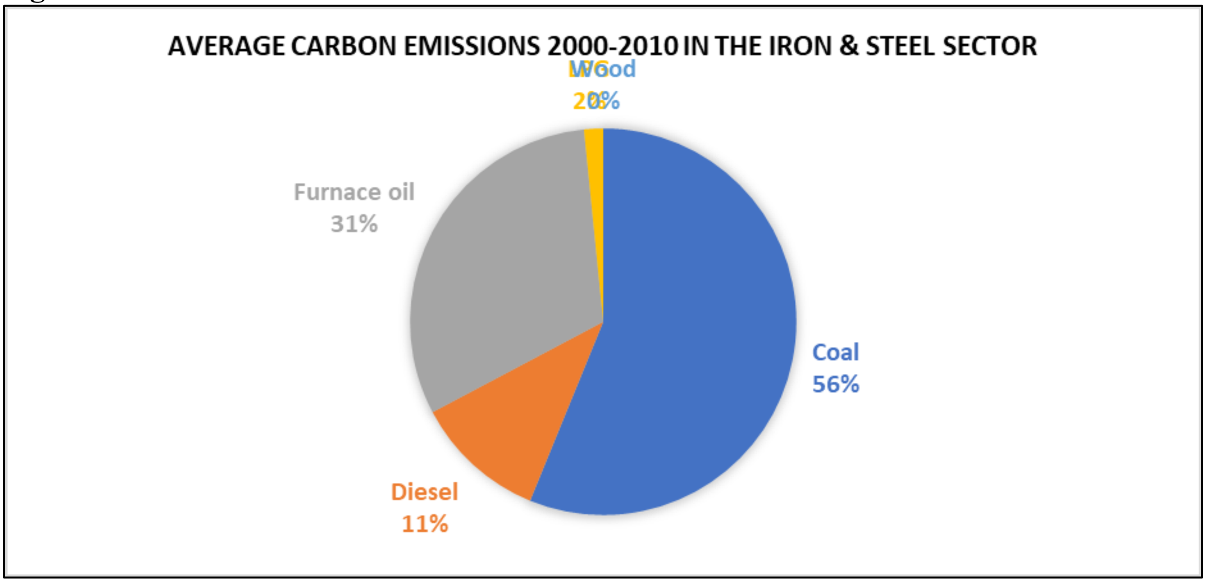
Source: Authors based on CMIE (Database)

In the iron and steel industry (Figure 2), we found that the dominance of coal as the primary emitter persisted throughout the initial decade. To draw Figure 2, the average emission from each energy source for 2000-2010 was calculated. A similar exercise was carried out for the 2011-2022 period. All of these would change according to the changes suggested per the CBAM Report structures under the various versions – the latest being the "Report Structure version 18.20 (release 1.2.2.0)," released on July 1, 2024.[11] However, an intriguing shift occurred in the subsequent decade, as furnace oil increased its share by 16%, effectively surpassing coal as the leading emission source. Concurrently, coal witnessed a corresponding decline in its contribution by 16%, marking a substantial redistribution in emission sources within the iron and steel industry. Furthermore, the role of diesel underwent a notable transformation, declining from an 11% share in the first decade to a mere 3% in the second decade. Conversely, LPG experienced a notable uptick, with its share rising by 8% over the same period. These pronounced alterations underscore dynamic shifts in energy source profiles within the iron and steel industry. In the appendix Figure 8, we have undertaken a similar exercise wherein we have included electricity as an energy source and we find that the sector is excessively using electricity compared to other energy sources.

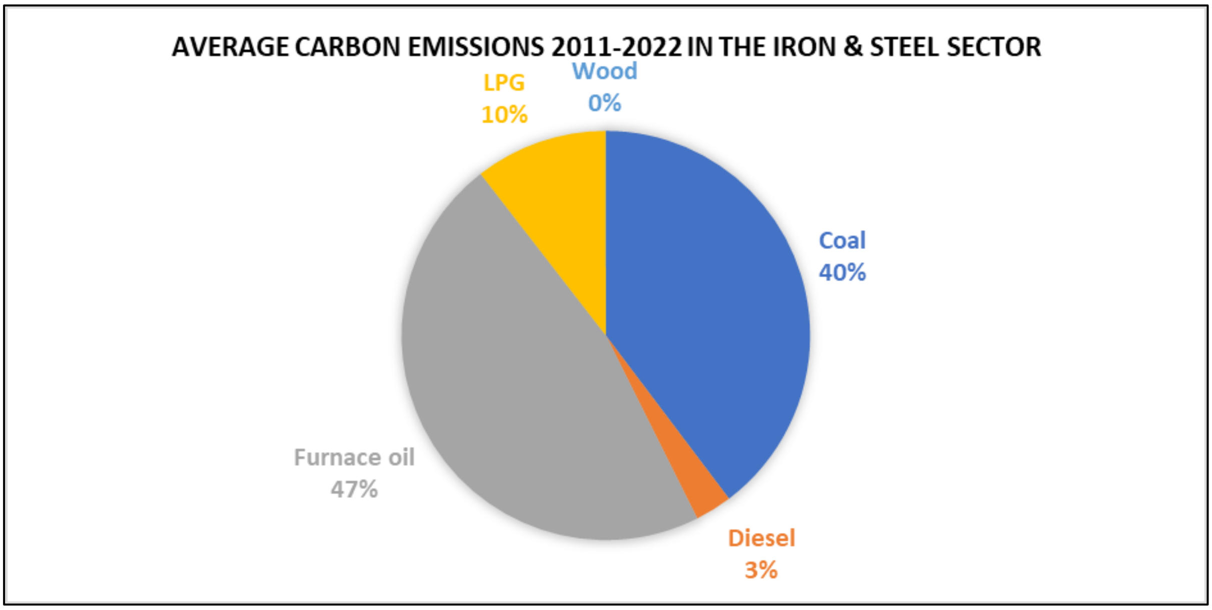
Further delving into the aluminum sector, examining emission sources over two distinct decades reveals no noteworthy trends. In the initial decade from 2000 to 2010, furnace oil emerged as the predominant contributor, constituting 44% of total emissions, followed closely by coal (39%). Subsequently, in the following decade (2011-2022), the dominance of furnace oil persisted, witnessing a slight increase to 46% of total emissions, solidifying its position as the primary emission source.

[11] See, https://taxation-customs.ec.europa.eu/document/download/28db4b61-da07-428a-9da1-9512c5aae61b_en?filename=CBAM%201.2.1.0%20release%20funcions%20for%20Declarant%20Portal.pdf.

Figure 2: Source of Carbon Emissions in the iron & steel sector



Source: Authors based on CMIE (Database)



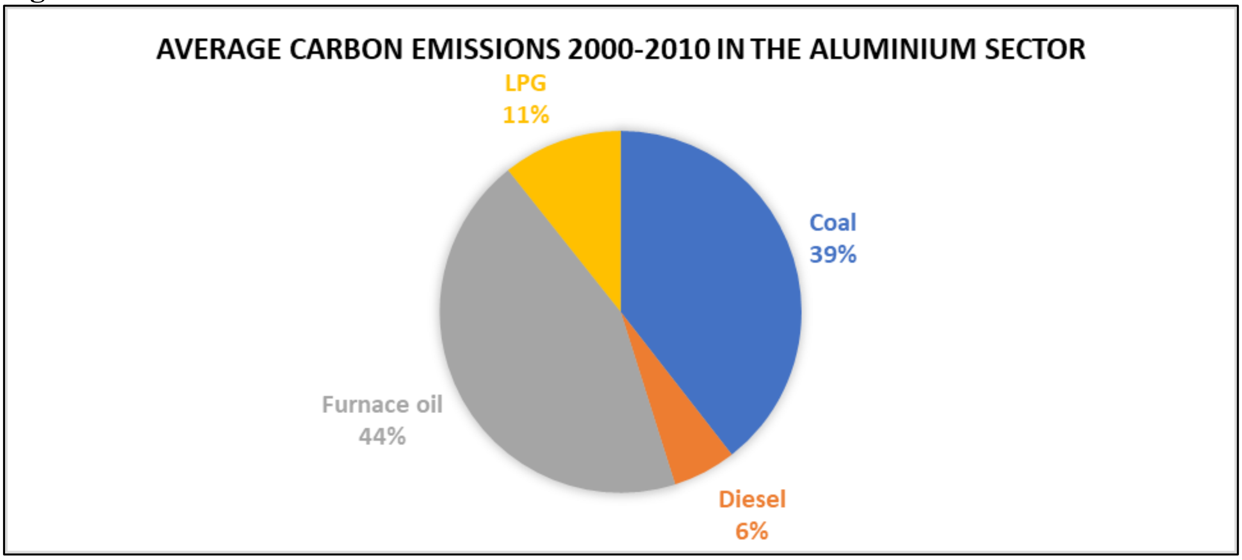
Source: Authors based on CMIE (Database)

Concurrently, coal remained the second-largest contributor, although it witnessed a marginal decline to 38% of total emissions. Notably, the share of LPG witnessed a 4% increase between the two decades, while diesel experienced a 5% decline. Companies in the aluminum industry have shifted from using diesel to embracing LPG. This can also be said for the iron and steel sector, as seen in Figure 2. One of the reasons for this trend is that firms are looking at infusing LPG supplies to replace a significant portion of diesel to cut carbon emissions and increase cost-effectively adopting cleaner fuels.[12] These shifts underscore that little changes in energy sources within the aluminum sector have occurred over the years, and firms in this industry have maintained the same energy source patterns over time. Moreover, the changes in emission and

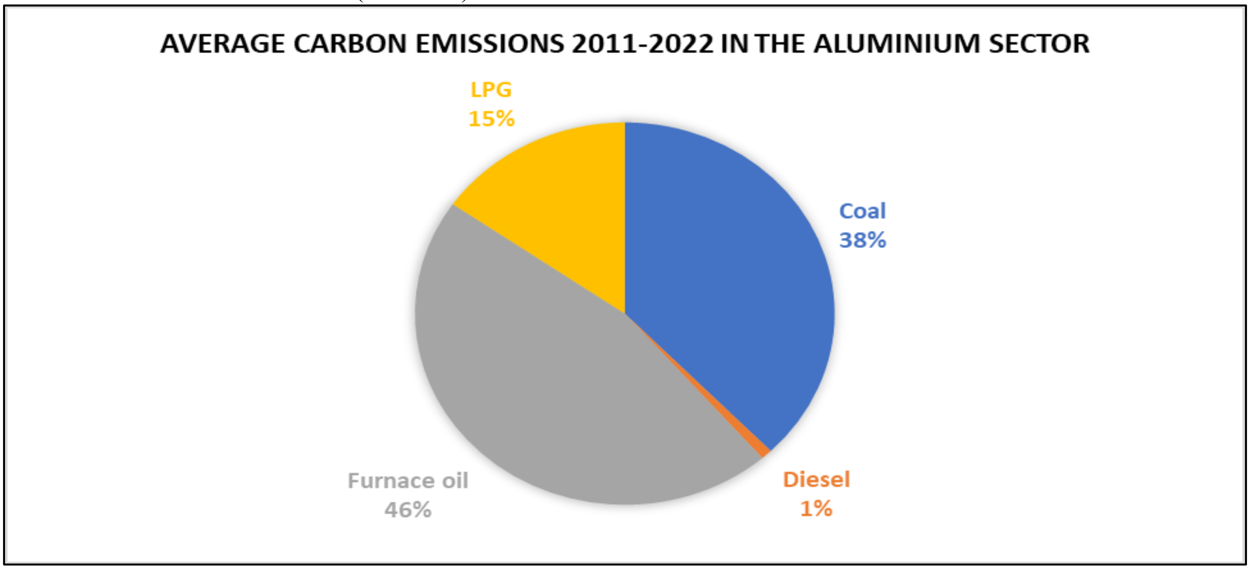
[12] https://www.moneycontrol.com/news/business/jsw-steel-mulling-lpg-gas-usage-in-gujarat-plant-amid-emission-goals-12305571.html

emission sources seen in the figures above reiterate that the two sectors in the Indian industrial sector are quite different. In the appendix Figure 9, we have undertaken a similar exercise wherein we have included electricity as an energy source and we find that the sector is excessively using electricity compared to other energy sources.

Figure 3: Source of Carbon Emissions in the Aluminium sector



Source: Authors based on CMIE (Database)

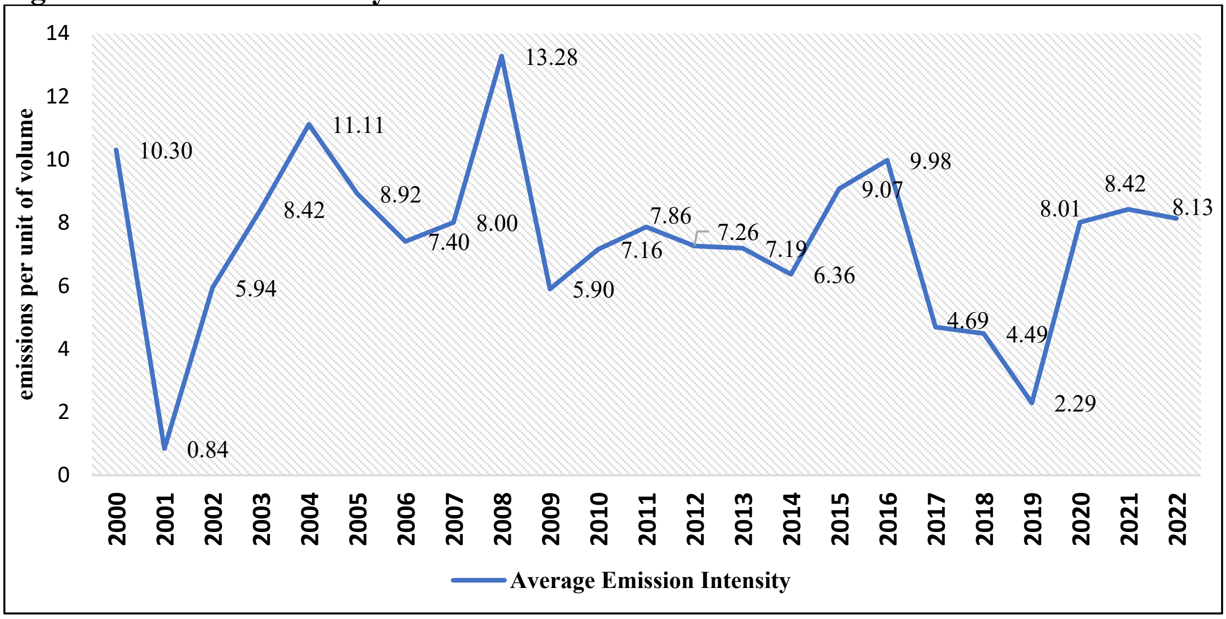


Source: Authors based on CMIE (Database)

As pointed out above, there is a gap in the literature in the context of India. To the best of our understanding, no studies specifically address the intensity of carbon emission among energy-intensive firms. In the figures below, we look at the trend in the two industries.

In the iron and steel sector, upon examining the data from 2000 to 2022, there needs to be a consistent trend or emission intensity pattern. The values fluctuate significantly yearly, indicating variability (figure 4) despite removing outliers. Firstly, changes in production levels and emissions influence the variation in carbon emissions intensity. Secondly, data reporting inconsistency by firms leads to very few data points to analyze, hence leading to fluctuation in emissions. In 2002, emission intensity peaked dramatically by around 600% from the previous year since the emission intensity was lowest in 2001 (0.84 tonnes of emissions per unit of output). In 2008, emission intensity peaked again because production dropped by 25%, and emissions increased significantly (122%). In 2018, emission intensity was relatively low at 4.49 tonnes of emissions per output unit, followed by a significant drop to 2.28 tonnes per production in 2019, the lowest value since 2001. After a notable drop in 2019, a period of increased emission intensity is seen till 2022. The rise in emission intensity during 2020 and subsequent years could be attributed to various factors, including disruptions caused by the COVID-19 pandemic and changes in economic activities affecting emissions.

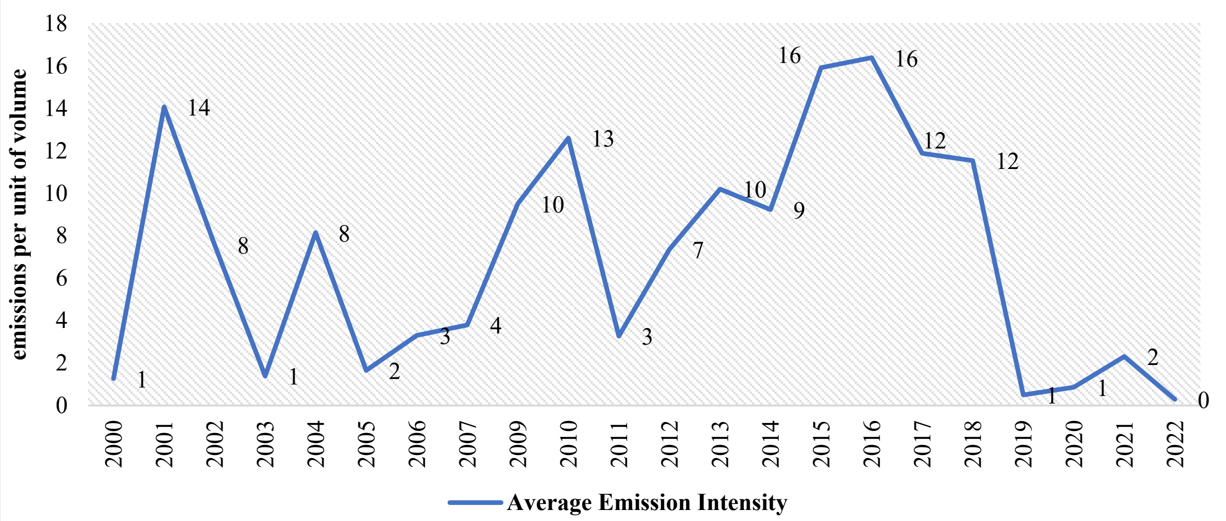
Figure 4: Emission Intensity in the iron & steel sector



Source: Authors based on CMIE (Database)

Even in the aluminum sector (figure 5), there is no discernible emission intensity pattern; the data shows more significant fluctuations than in the iron and steel industry. In 2000, emission intensity was relatively low at 1.27 tonnes of emissions per output unit. However, in 2001, emission intensity spiked dramatically to 14.06 tonnes of emissions per unit of output due to a significant increase in emissions of approximately 472% and a simultaneous decline in volume by 23%. A notable decline followed this spike in 2002, where emission intensity fell to 7.58 tonnes of emissions per unit of output and dropped to 1.39 tonnes per unit of production in 2003. In the mid-2000s, emission intensity remained relatively moderate. For instance, in 2004, it increased to 8.14 tonnes of emissions per unit of output, dropped to 1.66 tonnes per unit in 2005, and then fluctuated between 3 to 4 tonnes of emissions per unit of production in the subsequent years (2006 and 2007). From 2010 to 2018, emission intensity varied more significantly. It rose to 12.60 tonnes of emissions per output unit in 2010, then decreased to 3.27 tonnes per production unit in 2011. The highest values of average emission intensity during this period were observed in 2015 (15.91) and 2016 (16.39). Interestingly, from 2019 onwards, emission intensity dropped significantly. In 2019, average emission intensity declined by approximately 95%, the lowest in the dataset. This low trend in average emission intensity continued into 2020 (0.86), 2021 (2.31), and 2022 (0.29), indicating a sustained period of low average emission intensity. Between 2019-2022, the average emission intensity averaged around 0.99 tonnes of emissions per output unit.

Figure 5: Emission Intensity in the Aluminium Sector



Source: Authors based on CMIE (Database)

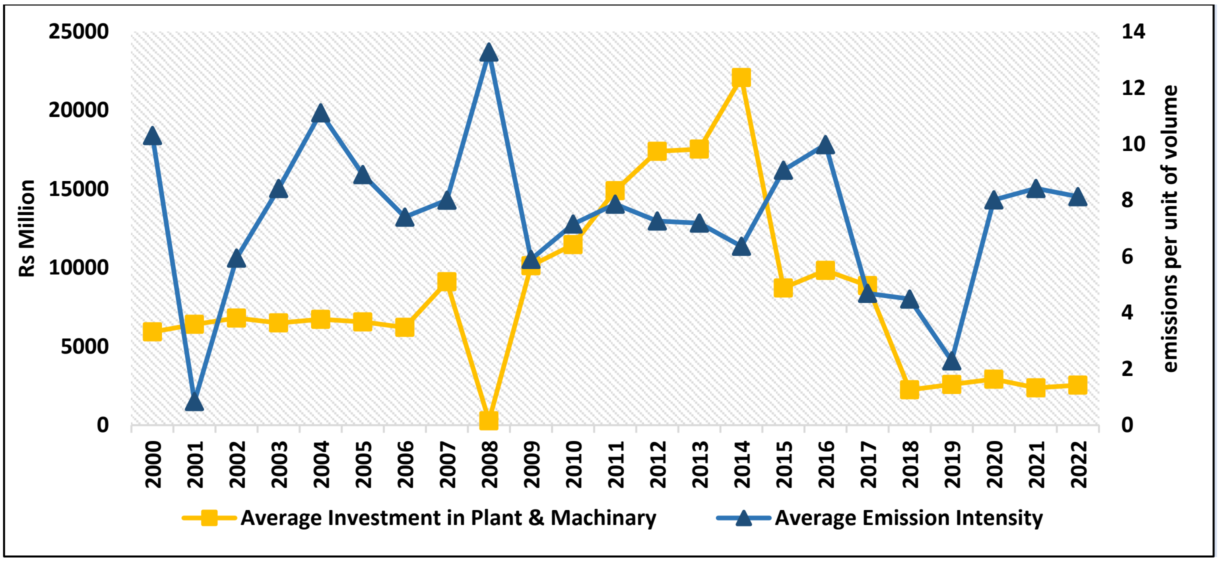
Notably, between 2000 and 2022, average emission intensity in the aluminium industry varied between 0.29 and 16.39 tonnes of emissions per unit of output. This range is substantially broader than that observed in the iron and steel industry, which ranged from 0.84 to 13.27 tonnes of emissions per production unit.

Capital investments play a crucial role in influencing carbon emission intensity. Considering this, we have analysed how investment in plant and machinery across both sectors has influenced emission intensity.

Investments in plant and machinery in the iron and steel sector show significant variability (Figure 6). Starting at Rs 5,925 million in 2000, investments gradually increased, peaking significantly in 2014. Notably, 2008 was an outlier with an extremely low investment of Rs 279 million, coinciding with the highest emission intensity. Low investment is primarily due to data constraints; very few firms reported their investment data in 2008.

Significant investments in plant and machinery from 2010 to 2014 align with periods of moderate emission intensities, indicating some positive impact. Moreover, there appears to be a partial correlation between investment and emission intensity. Higher investments in specific years correlate with lower emission intensities, such as in 2001, 2009, and 2014, to name a few. Since 2017, investment growth in the iron and steel sector has notably slowed, and emission intensity has remained uptick. Investments in plant and equipment in the aluminum industry generally showed an increasing trend (Figure 7). Starting at Rs 8,381 million in 2000, investments peaked in 2022 at Rs 64.302 million.

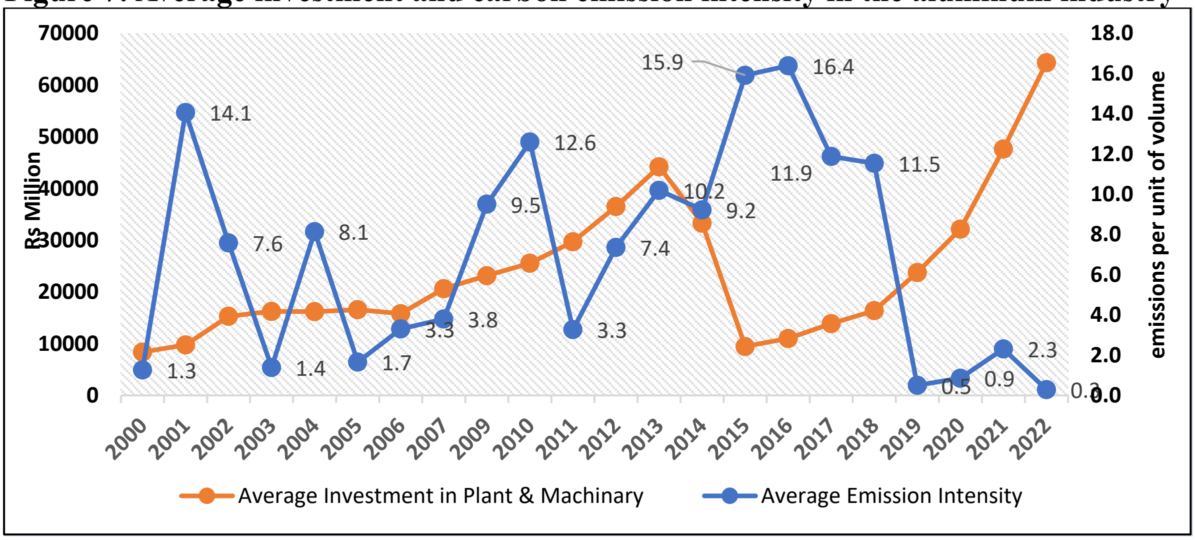
Figure 6: Average investment and carbon emission intensity in the iron and steel industry



Source: Authors based on CMIE (Database)

There are fluctuations, with some years showing lower investment, such as 2015, but the overall trend indicates growing investment over time. In the aluminum industry, a distinct trend became apparent after 2015, when two distinct trajectories emerged (Figure 7). Notably, as firms increase their investment in plant and machinery, emission intensity experiences a significant decline in the aluminum sector. The notable decrease in emission intensity in recent years, particularly from 2019 to 2022, correlates with increasing investments, suggesting that investment in plants and equipment substantially impacts reducing emissions. Overall, the sector has shown significant progress in lowering emission intensity over the two decades, particularly in recent years.

Figure 7: Average investment and carbon emission intensity in the aluminum industry



Source: Authors based on CMIE (Database)

Hence, in this section, having explored the carbon emission and emission intensity trends in the iron steel and aluminum sectors from 2000 to 2022, we move on to the empirical analysis. This section highlighted that both sectors showed increased emissions from 2008 to 2014 in common years. Emission intensity patterns in both sectors fluctuated, with no clear trend. We also found that the iron and steel sector's emission sources shifted significantly over two decades, with coal's dominance decreasing while furnace oil and LPG usage increased. In contrast, the aluminum sector showed consistent energy source patterns, with furnace oil and coal as primary contributors. Both sectors have made progress in reducing emission intensity, with notable improvements in recent years.

6. Results

The log-log nature of our dependent and independent variables necessitates the interpretation of percentages. A percentage increase in the investment in plant and machinery corresponds to a statistically significant decline in carbon emission intensity by 0.76 percent. This finding underscores the crucial role of capital investments in influencing carbon emission intensity. Firms that have made substantial investments in plant and machinery exhibit a capacity to mitigate carbon emissions, indicative of potential advancements in production techniques or shifts in production methodologies.

From a policy-making standpoint, the identified coefficient holds significance, offering insights into the financial implications of achieving global standards for carbon emission intensity. The negative coefficient of 0.76 percent serves as a guide for policymakers, aiding in determining financial resources required for existing firms to align their carbon emission intensity with international benchmarks – in this case, specifically the EU-CBAM.

Table 2: Results of the Regression Six Models

Variables	(1)	(2)	(3)	(4)	(5)	(6)
log (Investment in Plant and Machinery)	0.023	-0.139***	-0.769***	-0.769***	-0.632***	-0.771***
	(0.037)	(0.038)	(0.182)	(0.182)	(0.195)	(0.182)
log (Capital Intensity)		0.366***	1.012***	1.012***	0.629***	0.650***
		(0.028)	(0.184)	(0.184)	(0.186)	(0.185)
log (Sales)			0.656***	0.656***	0.988***	1.009***
			(0.185)	(0.185)	(0.185)	(0.184)
Age				-0.034	-0.034	-0.029
				(0.087)	(0.087)	(0.087)
log (Investment in Plant and Machinery) * Sector Dummy					-0.133*	
					(0.069)	
log (Investment in Plant and Machinery) * Exporter Dummy						0.007
						(0.008)
Constant	-0.002	-0.900**	-4.014***	-3.744***	-3.494***	-3.762***
	(0.400)	(0.396)	(0.964)	(1.272)	(1.278)	(1.272)
Firm fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
Observations (n)	3,796	3,796	3,796	3,796	3,796	3,796
R^2	0.483	0.508	0.510	0.510	0.511	0.510

Adjusted R^2	0.399	0.429	0.431	0.431	0.431	0.431
Residual Std. Error	0.886 (df = 3267)	0.864 (df = 3266)	0.862 (df = 3265)	0.862 (df = 3265)	0.862	0.862
F Statistic	5.773*** (df = 528; 3267)	6.384*** (df = 529; 3266)	6.418*** (df = 530; 3265)	6.418*** (df = 530; 3265)	6.418***	6.407***

Note: *p<0.1; ** p<0.05; P<0.01.

Source: Author.

Contrary to the findings of Sahu et al. (2013) and Goldar (2017), our analysis of energy-intensive sectors such as iron & steel and aluminium reveals a noteworthy result. An increase in the capital intensity of a firm results in a 1.012 percent increase in carbon emission intensity. This disparity may be attributed to the specific focus of our analysis on energy-intensive sectors, where larger firms in the steel industry often employ the Blast furnace method. This method emits more carbon than the electric arc furnace (EAF) method, which smaller firms typically follow. Consequently, the observed divergence in results underscores the sector-specific nuances in the relationship between capital intensity and carbon emissions.

Moreover, our study sheds light on the size factor, indicating that larger firms, as measured by total sales, tend to exhibit higher carbon emission intensity than their smaller counterparts. This finding aligns with the expectation that the scale of operations in larger firms may contribute to elevated carbon emissions. On the other hand, the age of a firm remains a minor factor in determining the carbon emission intensity of energy-intensive firms, suggesting that the environmental impact is more closely tied to contemporary operational practices than the historical establishment.

In Regression (5), our analysis reveals a distinction in the impact of higher investment in plant and machinery on emission reductions between the aluminium and iron, and steel sectors. Precisely, a 1 percent increase in investment in the iron and steel sector corresponds to an average 0.62 percent reduction in emission intensity. In contrast, a similar investment in the aluminium sector leads to a slightly higher emission intensity reduction of 0.76 percent. This suggests that, on average, comparatively higher investment in the iron and steel industry would be required to achieve emission intensity reductions similar to those in the aluminum sector.

In regression (6), where we incorporate the characteristics of exporting firms, the results defy our initial hypothesis. Surprisingly, we do not find statistically significant evidence supporting a stronger relationship between investment and emission intensity for exporting firms when compared to non-exporting counterparts. This unexpected finding might be attributed to the historical lack of carbon efficiency requirements for exporting firms. However, with the changing landscape of international trade rules, especially with the introduction of the Carbon Border Adjustment Mechanism (CBAM), it is plausible that exporting firms are poised to make more environmentally conscious investments in the near future.

7. Conclusion

The investigation into the carbon emission intensity within India's iron, steel, and aluminium sectors reveals significant trends and insights that have profound implications for policy-making and industry practices. From 2000 to 2022, a discernible trend of declining average carbon emission intensity becomes evident within the iron, steel, and aluminium industries. This reduction in emission intensity can be primarily attributed to a progressive shift towards embracing renewable energy sources, notably solar and wind power, by various firms operating within these sectors. As these industries increasingly harness cleaner energy alternatives, the consequential outcome has been a consistent mitigation of emission intensity over time. Another aspect is that many of these industries are in the formal sector and hence would be aware of the regulatory changes being proposed across the border in the EU.

However, it is essential to acknowledge that the extent of this reduction is influenced by the adoption of renewable energy and the specific production techniques chosen by individual firms. Another aspect is that this paper does not delve into the intricate interplay of these production techniques, leaving room for further exploration and understanding. Empirical analysis highlights an inverse and significant relationship between investment in plant and machinery and carbon emission intensity. This finding underscores the necessity for continuous investment in advanced technologies to enhance energy efficiency and reduce emissions.

If CBAM is implemented, small and medium-sized firms will be most affected. The ambiguity lies in whether the carbon tax will apply to individual firms or entire industries. If it's calculated based on average industry emissions, small firms could face adverse effects. Therefore, it is crucial to devise a package that supports SMEs in upgrading their technology to adapt. Gupta et al. (2024) suggest implementing the Carbon Border Adjustment Mechanism (CBAM) will affect exporters' profitability and trade competitiveness. This measure will likely benefit nations with advanced decarbonization capabilities and well-established carbon pricing mechanisms. To navigate this shift, India is advised to reinforce its emission monitoring, reporting, and verification (MRV) systems and enhance its carbon pricing frameworks.

Lastly, we recommend that policymakers prioritise facilitating access to finance for technological upgrades and foster closer collaborations with industry in order to aid them in maintaining international competitiveness.

References

Costantini, V., & Mazzanti, M. (2012). On the green and innovative side of trade competitiveness? The impact of environmental policies and innovation on EU exports. *Research Policy*. *41*(1), 132-153.

Bagchi, P., Sahu, S. K., Kumar, A., & Tan, K. H. (2022). Analysis of carbon productivity for firms in the manufacturing sector of India. *Technological Forecasting and Social Change*. *178*, 121606.

Gupta, A., Pandey, R., & Sapatnekar, S. (2024). *Potential implications of the EU's Carbon Border Adjustment Mechanism*. (No. 24/408).

Government of India (2020) Ministry of Steel, Annual Report 2020-21.

Goldar, B. (2012). Input substitution and technical change in Indian manufacturing, 1973–2007. *Journal of Industrial Statistics*. *1*(2), 169-81.

Goldar, B., & Bhalla, M. (2015). Scope for reducing CO 2 emissions of Indian manufacturing: Its likely impact on export competitiveness. *Journal of International Commerce, Economics and Policy*. *6*(03), 1550018.

Goldar, B., Parida, Y., & Sehdev, D. (2017). Reduction in carbon emissions intensity and impact on export competitiveness: Evidence from Indian manufacturing firms. *Journal of International Commerce, Economics and Policy*. *8*(02), 1750012.

Goldar, B., & Goldar, A. (2023). Impact of export intensity on energy intensity in manufacturing plants: Evidence from India. *The Journal of International Trade & Economic Development*. *32*(4), 639-664.

Goldar, B. (2023). ICT Investment, Adoption of ISO 14000 Certification, and Export Performance in Indian Manufacturing Plants. *Journal of Quantitative Economics*. *21*(3), 523-553.

Kumar, S. S., & Narayanan, K. (2014). Carbon dioxide emissions from Indian manufacturing industries: Role of energy and technology intensity. *Review of Business and Economics Studies*. (1), 60-73.

Lanoie, P, M Patry and R Lajeunesse (2008). Environmental regulation and productivity: New findings on the Porter hypothesis. *Journal of Productivity Analysis*. 30, 121–128.

Porter, M. E., & Linde, C. V. D. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of economic perspectives*. *9*(4), 97-118.

Rubashkina, Y., Galeotti, M., & Verdolini, E. (2015). Environmental regulation and competitiveness: Empirical evidence on the Porter Hypothesis from European manufacturing sectors. *Energy policy*. *83*, 288-300.

Sahu, S., & Narayanan, K. (2011). Determinants of energy intensity in Indian manufacturing industries: a firm level analysis. Eurasian Journal of Business and Economics. 4(8). 13-30.

Sahu, S. K., & Narayanan, K. (2014). Energy use patterns and firm performance: Evidence from Indian industries. *The Journal of Energy and Development*. *40*(1/2), 111-133.

Sahu, S. K., & Mehta, D. (2018). Determinants of energy and CO2 emission intensities: a study of manufacturing firms in India. *The Singapore Economic Review*. *63*(02), 389-407.

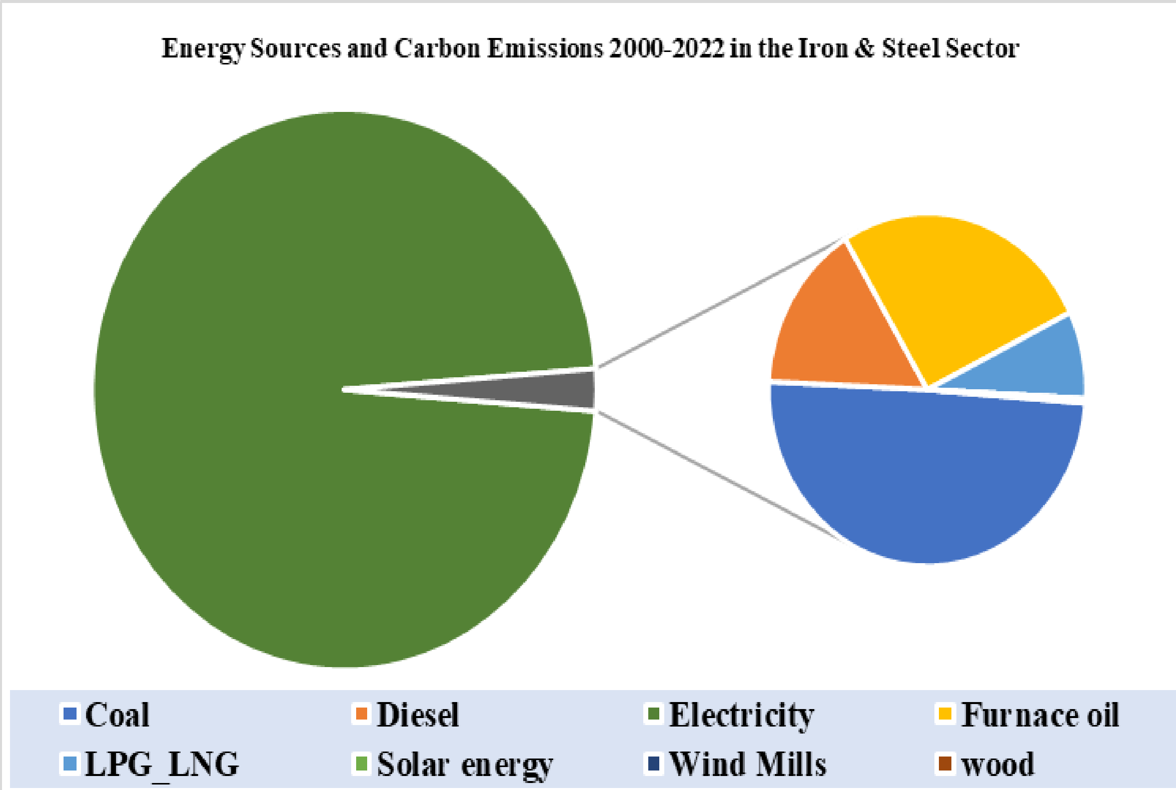
Van Leeuwen, G., & Mohnen, P. (2017). Revisiting the Porter hypothesis: an empirical analysis of green innovation for the Netherlands. *Economics of Innovation and New Technology*. *26*(1-2), 63-77.

Annexure

Annex Table 1: NIC codes used in the Analysis

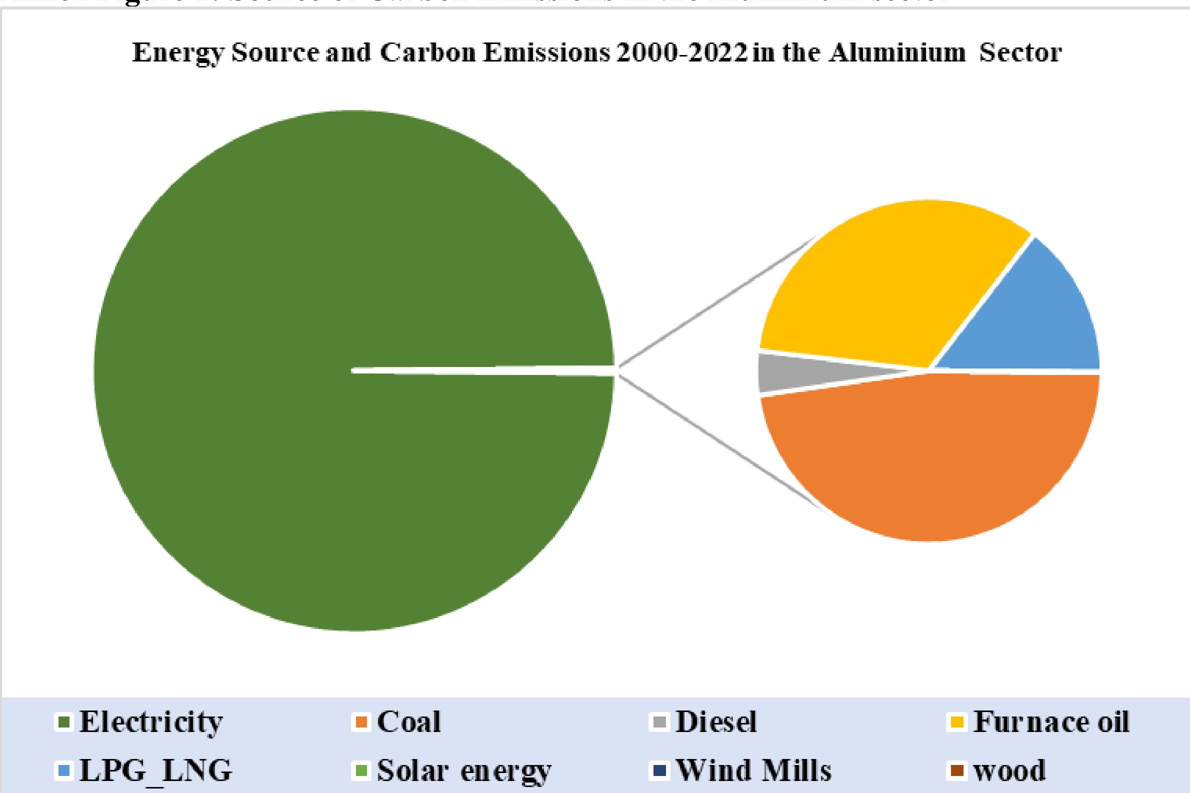
NIC Codes	Description
2410	Manufacture of basic iron and steel
2420	Manufacture of basic precious and other non-ferrous metals
24101	Manufacture of pig iron and spiegeleisen in pigs, blocks, or other primary forms
24102	Manufacture of direct reduction of iron (sponge iron) and other spongy ferrous products
24103	Manufacture of steel in ingots or other primary forms and other semi-finished products of steel
24104	Manufacture of Ferro-alloys
24105	Manufacture of hot-rolled and cold-rolled products of stee
24106	Manufacture of tube and tube fittings of basic iron and steel
24108	Manufacture of wire of steel by cold drawing or stretching
24109	Manufacture of other basic iron and steel n.e.c
24201	Manufacture of Copper from ore and other copper products and alloys
24202	Manufacture of Aluminium from alumina and by other methods and products of aluminium and alloys
24203	Manufacturing of lead, zinc and tin products and alloy
24209	Manufacture of other non-ferrous metals n.e.c.
24311	Manufacture of tubes, pipes and hollow profiles and of tube or pipe fittings of cast-iron/cast-steel
24319	Manufacture of other iron and steel casting and products thereof
25111	Manufacture of doors, windows and their frames, shutters and rolling shutters, gates and similar articles used on buildings
25112	Manufacture of metal frameworks or skeletons for construction and parts thereof ((towers, masts, trusses, bridges, etc.)
25113	Manufacture of industrial frameworks in metal (frameworks for blast furnaces, lifting and handling equipment etc.)
25119	Manufacture of other structural metal products
25121	Manufacture of metal containers for compressed or liquefied gas
25122	Manufacture of metal reservoirs, tanks, and similar containers
25129	Manufacture of other containers n.e.c.
25991	Manufacture of metal fasteners (nails, rivets, tacks, pins, staples, washers, and similar non-threaded products and nuts, bolts, screws, and other threaded products)
25995	Manufacture of metal sanitaryware such as baths, sinks, washbasins and similar articles
25999	Manufacture of other fabricated metal products n.e.c.

Annex Figure 1: Source of Carbon Emissions in the Iron & Steel sector



Source: Authors based on CMIE (Database)

Annex Figure 2: Source of Carbon Emissions in the Aluminium sector



Source: Authors based on CMIE (Database)

Annex Table 2: Summary Statistics Table

	Emission Intensity	Age	Sales	Investment in Plant and Machinery	Capital intensity
unit	Numeric	Numeric	Numeric	Numeric	Numeric
Min.	0.0	0.0	0.3	3.6	0.5
1st Qu.	0.057	15	629.9	174.5	17
Media	0.175	23	1,777.2	558.5	38.7
Mean	15.568	25.27	13,718.1	11,470.7	336.5
3rd Qu.	0.591	32	4,968.9	2,386.7	76.3
Max.	7,092.982.0	125	15,32,127.9	12,84,244.3	4,65,160.0
Not A's		25		81	81

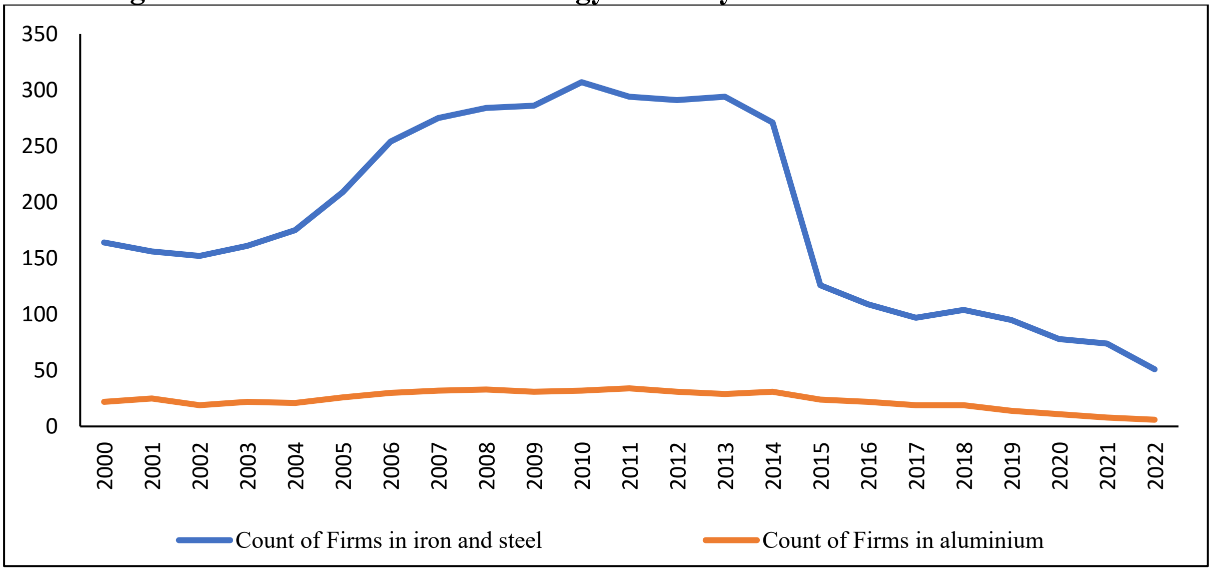
Source: Authors.

Annex Table 3: Number of Firms in each year

Year	Number of Firms in Iron and Steel	Number of Firms in Aluminium
2000	164	22
2001	156	25
2002	152	19
2003	161	22
2004	175	21
2005	209	26
2006	254	30
2007	275	32
2008	284	33
2009	286	31
2010	307	32
2011	294	34
2012	291	31
2013	294	29
2014	271	31
2015	126	24
2016	109	22
2017	97	19
2018	104	19
2019	95	14
2020	78	11
2021	74	8
2022	51	6

Source: Authors based on CMIE (Database)

Annex Figure 3: Number of Firms in energy-intensity Industries



Source: Authors based on CMIE (Database)

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