CHAPTER FIVE

DRIVING FACTORS OF CARBON EMISSIONS IN THE INDIAN CORE INDUSTRIES

Overview: The present chapter focuses on fulfilling Objective 2, whose primary motivation is to identify the driving factors of the core industries' emission levels in India. The study specifically aims to investigate the economic, industrial, demographic and environmental factors that significantly affect the carbon emission levels of the core industries. Based on the empirical results, appropriate industrial and environmental regulations can be put in place for environmental benefits.

5.1. Introduction:

Pollutants and greenhouse gases released during manufacturing and producing industrial activities are referred to as industrial emissions. The combustion of fossil fuels, chemical reactions, and other industrial processes are the main sources of these emissions, which greatly contribute to the pollution of the air, water, and soil. A primary cause of climate change that has an impact on the environment and public health is industrial emissions. Adopting greener technology, increasing energy efficiency, and implementing effective regulations in practice are necessary to reduce these emissions. It is essential to comprehend the causes and effects of industrial emissions in order to create sustainable plans that strike a balance between environmental preservation and economic growth. Due to rising concerns, firms and industries have initiated various sustainable practices in the modern business world to limit their impact on the environment. The environmental threats of the Indian core industries have been highlighted in the earlier chapters, despite their significant economic contribution to the country's industrial growth. The mere acknowledgement of the industries' polluting attributes will not provide specific insights into controlling their environmental degradation levels. Therefore, the researcher intends to explore the driving factors of the core industries' carbon emission levels. To do so, the potential factors are divided into four categories - economic, industrial, demographic, and environmental. The empirical outcomes of this chapter are believed to guide policymakers in taking more specific measures to enable sustainable growth of the core industries.

In the existing literature, studies have been found focusing on the various drivers of carbon emissions. Economic growth (Jalil and Feridun, 2011; Udemba, 2020), financial development (Sehrawat *et al.*, 2015; Shahbaz *et al.*, 2020), population (Asumadu-Sarkodie and Owusu, 2017a; Lin *et al.*, 2015), urbanization (Boamah, 2022; Yu and Xu, 2019), industrialization (Asumadu-Sarkodie and Owusu, 2017a; Zafar *et al.*, 2020), energy consumption (Nathaniel *et al.*, 2020; Xu *et al.*, 2018), etc. are a few of the most common determinants whose effects on carbon emissions have been adequately investigated in prior studies. However, these studies are carried out on economic levels, failing to identify what causes industrial emissions in particular. Moreover, these studies have found mixed findings regarding these variables, proving that their effects differ from country to country. A detailed explanation of these studies has been mentioned in Chapter 2. Considering such gaps, it is vital to explore the significant drivers that influence the core industries' emission levels in India and assess the nature of the impact on the same. Moreover, the empirical analyses of the present chapter include new potential variables whose possible effects are not yet observed in the existing literature. Such exploration will be a significant addition to the existing literature, providing more specific direction for policymakers to facilitate sustainable growth of the Indian industries.

5.2. Hypothesis development:

Economic growth: Studies have shown that economic growth affects an economy's emission levels, either directly or inversely depending on the level of growth. A positive relationship can be expected between economic growth and carbon emission levels, mostly in less-developed or developing countries. As Udemba (2020) argued, when an economy is developing, it primarily focuses on becoming self-sufficient and economically advanced. Throughout this stage, very little attention is on the environmental aspects of the various investments and activities that are undertaken to attain economic growth. The primary focus of developing economies is to increase production levels. In that case, if the technologies are inefficient and energy sources rely on fossil fuels, a positive relationship between economic growth and carbon intensity level can be expected (Sharma *et al.*, 2021). Lin *et al.* (2015) stated that economic growth is expected to increase people's income levels and living standards. Hence, the demand for industrial products and energy is expected to rise constantly, leading to higher emission levels and causing harm to the environment. On the other hand, studies have also empirically evidenced decreasing emission levels from economic growth (Asumadu-Sarkodie and Owusu, 2017a; Elfaki *et al.*, 2022). With a growing economic progression, the nation has the capability of overcoming the above-stated environmental hindrances. It is expected to bring advanced technology, better energy sources, and more efficient resources to the nation, which can reduce environmental degradation levels. However, this negative effect is expected to be more prominent in developed economies. Scholars have argued that in the initial years of growth, economic growth causes emission escalations due to the above-explained reasons. Only after reaching a certain threshold limit can economic growth help reduce environmental deterioration (Dinda, 2004; Panayotou, 1993).

As India is still in its developing phase, its current transition phase towards industrialization is expected to positively impact industries' carbon emission levels due to the lack of adequate environment-friendly technologies and resources. Based on these arguments, the present study formulates the following alternative hypothesis to test the relationship between India's economic growth and industrial emissions.

$H_{2.1}$: There exists a significant positive relationship between economic growth and core industries' carbon emission levels in India.

Foreign direct investments: Studies have shown that an economy's carbon emission levels are heavily dependent on a nation's FDI. For a country's environmental health, FDI can go either of the two ways: a boon or a bane. If FDI focuses primarily on scaling up production and operation levels, it may lead to higher emissions for industries. Past studies have already highlighted the possibility of FDI leading to higher pollution (Adamu *et al.*, 2019; Huang *et al.*, 2022; Sreenu, 2022). On the contrary, FDI can also facilitate the sharing of knowledge and technologies with the host country and help control emission levels (Kirkulak *et al.*, 2011; Nathaniel *et al.*, 2020; Yu and Xu, 2019). Technological upgradation can result in higher production without causing significant environmental damage. Adeel-Farooq *et al.* (2021) empirically argued that while FDI from developed countries may benefit the ecological balance, FDI from developing countries can harm the host country's environmental health. Hence, the source of FDI also plays a vital role in determining its effect on the environment. Adamu *et al.* (2019) propose that the Indian government should promote and facilitate sustainable FDI inflows, which can help reduce emission levels. FDIs will improve environmental quality only if they bring a cleaner production process and advanced infrastructure development to the host countries.

The above arguments indicate a lack of concrete evidence to comment on the direction of the effect of FDI on the core industries' carbon emissions. Hence, the following alternative hypothesis is formulated.

> ***H*$_{2.2}$**: There exists a significant positive relationship between FDI and core industries' carbon emission levels in India.

Agricultural production: The level of agricultural activity can have a significant impact on industrial carbon emission levels, especially for an agrarian economy like India. India is burdened with the need to provide sufficient food supply for its massive population. As the population has been continuously rising, demand for agricultural activities also continues to increase, ultimately affecting the country's environmental aspect. Studies have shown that when agricultural lands are expanded to increase production, they are often extended to forest areas, which causes severe issues of deforestation (Doggart *et al.*, 2020; Shapiro *et al.*, 2023). In such cases, an increase in emission levels becomes an obvious consequence. Furthermore, the agricultural sector necessitates energy consumption at every step, relying on electricity, fossil fuels, and so on. Overall, the emission levels are significantly affected by the usage of synthetic fertilizers (Menegat *et al.*, 2022), agricultural machinery (Guan *et al.*, 2023), manure storage (Wang *et al.*, 2022), livestock inventory (Ullah *et al.*, 2018), etc.

As per the above-stated arguments, India's growing agricultural sector is expected to increase the emission levels of the core industries, as these industries are also directly or indirectly related to agricultural operations. Hence, the alternative hypothesis is formulated to be tested as follows:

> ***H*$_{2.3}$**: There exists a significant positive relationship between agricultural production and core industries' carbon emission levels in India.

Research and development: Technological innovation is one of the most fundamental requirements for reducing the carbon emission levels of an economy or industry. A developing country like India needs to pay extensive attention to innovating advanced and environmentally friendly technology and resources so that industries can cater to its vast population's production demands with minimal pollutant emissions. In doing so, more financial and non-financial support must be offered to the industries for their research and development (R&D) activities to promote innovation. Past studies have depicted the environmental benefits of innovation through R&D investments (Balsalobre-Lorente *et al.*, 2021; Qayyum *et al.*, 2021; Sharma *et al.*, 2021). R&D encourages technological upgrades that help increase the productivity of industries without compromising the country's environmental health. Balsalobre-Lorente *et al.* (2021) particularly mentioned the welfare of R&D, which focuses on energy innovation. Over half of India's energy generation comes from fossil fuels (Energy Institute Statistical Review of World Energy, 2023), indicating that the country desperately needs to encourage more renewable energy production in order to create a healthier industrial environment. In that case, it is only R&D activities that can help attain such necessities.

The previous literature clearly defines that a country's R&D always result in lower emissions. The present study, therefore, formulates the following alternative hypothesis to be empirically tested:

> ***$H_{2.4}$***: There exists a significant negative relationship between R&D and core industries' carbon emission levels in India.

Industrialization: India is a developing agrarian economy that is transforming into modern industrialization. Such transformation in a developing economy often guarantees a rise in carbon emission levels (He *et al.*, 2013). The positive effects of industrialization have been confirmed by past studies in different geographical locations (Aslam *et al.*, 2021; Asumadu-Sarkodie and Owusu, 2017b; Mahmood *et al.*, 2020; Pata, 2018). Industrialization results in higher scales of production and manufacturing activities, leading to more energy consumption, waste dumping, and depletion of natural resources (Opoku and Aluko, 2021; Zafar *et al.*, 2020). Especially, the industrialization process of Asian countries is not very environment-friendly. Zafar et al. (2020) argued that the industrialization phase of Asian countries is mostly driven by heavy industries that primarily rely on non-renewable, highly polluting energy sources. However, industrialization can also be responsible for decreasing emission levels (Elfaki *et al.*, 2022; Lin *et al.*, 2015; Xu *et al.*, 2022). Rai and Rawat (2022) stated that if innovation and technological upgradation become the utmost priority of industrialization, it can benefit the environment. Lin et al. (2015) asserted that to save costs and survive long in the market, firms start innovating and adopting renewable energy sources, which protect the environment from possible harmful effects. Moreover, when industrialization takes place, awareness among the stakeholders also rises. As today's stakeholders are environmentally very much concerned, they push industries to become more sustainable and play a key role in initiating a greener industrial movement.

As per the earlier findings, there is a lack of concrete conclusions regarding the relationship between India's industrialization and its effect on the core industries' emission levels. Hence, the study formulates the following alternative hypothesis:

> ***$H_{2.5}$***: There exists a significant positive relationship between industrialization and core industries' carbon emission levels in India.

Energy consumption: In achieving India's economic growth, energy demand and consumption volume are expected to rise constantly in the coming years. Past studies have highlighted the possibility of causing significant environmental degradation through energy consumption in both developing and developed countries (Dogan and Turkekul, 2016; Nathaniel *et al.*, 2020; Sehrawat *et al.*, 2015). Especially, energy generation from fossil fuel sources is considered highly polluting. Therefore, to fulfil the growing energy demands, governments and modern industries should prioritize facilitating renewable energy consumption. Studies have shown that renewable energy consumption can significantly improve a nation's environmental quality (Balsalobre-Lorente *et al.*, 2018; Nathaniel *et al.*, 2020; Qayyum *et al.*, 2021). Unfortunately, industries in developing countries often depend primarily on fossil fuel sources for energy generation. In India, coal, oil, and biomass still accommodate over 80 percent of the total energy demands (IEA, 2021). In 2021, 78 percent of total electricity production in India is sourced from fossil fuels only (Energy Institute Statistical Review of World Energy, 2023).

Therefore, India's heavy dependence on conventional, high-polluting fossil fuels hints that industries' energy consumption is expected to add to the core industries' carbon emission levels. Hence, the following alternative hypothesis is formulated:

> ***$H_{2.6}$***: There exists a significant positive relationship between energy consumption and core industries' carbon emission levels in India.

Financial support: The financial sector is a significant factor that can affect industries' emission levels. Studies that have found a positive relationship between financial development and carbon emissions argue that if high-polluting industries can easily access funds, they have a higher chance of increasing emission levels (Qayyum *et al.*, 2021). Bui (2020) explains that with more credit availability, industries can invest more in their machinery and equipment to increase production. As a result, encouraging higher industrial production and consumption scales contributes to higher emissions levels. Boutabba (2014) empirically demonstrated the positive relationship between financial development and environmental degradation in India. In contrast, financial development can channel resources and funds to industries for R&D and environment-friendly projects. It ensures technological innovation and energy efficiency, lowering environmental degradation (Tamazian *et al.*, 2009). Shao et al. (2022) documented that financial development reduces the cost of raising funds for industries by facilitating capital access. Considering this cost relief, industries can focus more on being environmentally efficient to emit less carbon.

Based on the above discussions, the expected outcome of financial development on the carbon emission levels of India's core industries is inconclusive. Hence, the present study formulates the following alternative hypothesis to be tested empirically.

> $\boldsymbol{H_{2.7}}$: There exists a significant negative relationship between financial support and core industries' carbon emission levels in India.

Industrial design: Industrial design is a significant element of industrial innovation related to the physical attributes of the industrial outputs, determining the physical form and features of a product. In this modern era of environmental deprivation, the 'sustainable product design' concept has become popular among stakeholders lately. Engineers are constantly working on designing products that are environmentally safe, harmless, and result in low pollutants (He and Yu, 2021; Zheng *et al.*, 2021). The modern designs and compositions of the products are expected to minimize environmental deterioration and promote a sustainable environment (Amato *et al.*, 2020; Mesa *et al.*, 2019). However, studies have not been found in the past literature that have empirically explored the possible impact of industrial design on carbon emission levels. Therefore, the present study investigates whether the industrial design of the core industries has any environmental benefits or is involved in its deterioration.

Due to the lack of prior evidence with regard to India's industrial design, the following alternative hypothesis has been formulated to explore the impact of industrial design:

> $\boldsymbol{H_{2.8}}$: There exists a significant negative relationship between industrial design and the core industries' carbon emission levels in India.

Population density: Studies have revealed that population can be a major driver of overall carbon emission levels in a country, and the same can be applied to industrial emissions also. Population density reflects the volume of population per unit area. When population density grows, the pressure on the environment also increases with limited resources (Danish *et al.*, 2021; Ray and Ray, 2011). A growing population creates a burden for the economy to fulfil the massive volume of product demands. In order to meet the targets, the economy is compelled to increase the production levels of the industries (Lin *et al.*, 2016). In developing countries, an increase in industrial operations generally leads to a rise in emissions levels because of their poor infrastructure, technology, and high reliance on fossil fuel energy sources. In a nutshell, population density can affect an economy's environmental health through the means of production and consumption behaviour, raising the volume of energy demands. Especially if population growth leads to greater energy consumption, industrialization and transportation activities while continuing to rely on fossil fuel sources (Aslam *et al.*, 2021; Ohlan, 2015).

India, being a developing economy, faces similar difficulties with the growing population density due to its technological and infrastructural setbacks. Considering this, the present study formulates the following alternative hypothesis.

> $H_{2.9}$: There exists a significant positive relationship between population density and the core industries' carbon emission levels in India.

Urbanization: Urbanization is the rate of people shifting from rural areas to urban locations with the expectation of bringing modernization and upliftment of standards of living to the table (Ahmad and Zhao, 2018). In recent years, India has shifted its focus from the rural agricultural sector to the urban industrial sector, which accelerates urbanization in the country (Liddle, 2013). Often, a country's level of economic growth is judged by the rate of urban development because it promotes industrial expansion and other modern facilities (Wang and Wang, 2017). At the same time, it invites the risks of increased energy consumption and industrial emissions from the human-induced combustion of fossil fuels (Afriyie *et al.*, 2023; Mahmood *et al.*, 2020). Due to the expansion of the households and industrial setups, the overall energy demand increases from the residential and household segments, which leads to the risk of greater emissions. However, the benefits of urbanization are also found in past studies (Ahmad *et al.*, 2019; Martínez-Zarzoso and Maruotti, 2011; Sadorsky, 2014a). It promotes the concentration of industrial settings in urban locations and facilitates economies of scale. Urbanization can also encourage the use of modern, eco-friendly energy resources to replace harmful traditional energy fuels. It allows for better management of natural resources compared to rural zones (Martínez-Zarzoso and Maruotti, 2011). Moreover, urbanization can potentially offer infrastructural development and modern technological upgrades to industries (Ahmad *et al.*, 2019). Apart from technological advancements, urbanization also helps mitigate industrial pollution by introducing more effective environmental regulations (Sadorsky, 2014a). In these instances, urbanization can lead to environmental benefits, reducing the magnitude of industrial emissions.

Hence, prior studies have highlighted both favourable and unfavourable impacts of urbanization on emission levels. Based on these inconclusive arguments, the following alternative hypotheses are formulated:

> $\boldsymbol{H_{2.10}}$: There exists a significant positive relationship between urbanization and the core industries' carbon emission levels in India.

Poverty: The United Nations has acknowledged that the poor section of society fails to manage its environmental investments and is rather forced to exploit natural resources for survival purposes. Their basic instinct is to survive and are solely focused on that, without being able to consider the intentions of any environmental or social contribution towards society (United Nations Development Programme, 2022). At the same time, studies have revealed that the reduction of poverty also incorporates certain risks of environmental degradation. To eradicate poverty, more economic and industrial activities have to be commenced, leading to greater chances of industrial emissions. Wollburg *et al.* (2023) argued that an economy must compromise its environmental health to an extent in order to exterminate extreme poverty. With a higher income level, a higher level of energy consumption also takes place. For these reasons, the matter of poverty has become a delicate matter from the e environmental concerns, especially in developing countries.

Therefore, it can be assumed that the poverty of a nation will lead to environmental deterioration and to empirically test the proposition, we have formulated the following alternative hypothesis.

H $_{2.11}$: There exists a significant positive relationship between poverty and the core industries' carbon emission levels in India.

Education: Education determines the consumers' attitudes and consumption behaviour. Educated people are more aware and understanding of the ongoing global climate issues, and it encourages them to become responsible citizens. Education is one factor that provides essential skills to future generations for safeguarding the nation's green health (Palmer and Neal, 1994). A good education system is expected to provide social, cultural, environmental, and economic knowledge and values to the young population that promote the overall welfare of the country (Irish Aid Department of Foreign Affairs, 2016). When the population becomes more active and apprehensive regarding the ecological conditions of the country, they pressure the industries to also follow sustainable practices.

Based on the above arguments, it is indicated that education can lead to a healthier nation with a concerned stakeholder profile. Therefore, the alternative hypothesis is formulated as shown below:

H $_{2.12}$: There exists a significant negative relationship between education and the core industries' carbon emission levels in India.

Tree cover loss: Tree cover loss or deforestation is the most basic cause of increasing global warming and climate change issues. Forest area preservation is the natural progression for solving the ongoing environmental issues related to industrial growth because trees can capture and store carbon elements safely in the environment (Raihan *et al.*, 2022). However, when trees are cut down, the level of the natural process of carbon removal from the environment is compromised, leading to higher risks of emission volume. In fact, tree cover loss resulting from nations' economic activities has become a serious issue for escalating global emissions (Minlah *et al.*, 2021). However, empirical studies have not been found in the existing literature regarding the direct effect of tree cover loss on industrial emissions. Taking this into account, the study formulates the following alternative hypothesis to be empirically tested in the context of the Indian core industries:

H $_{2.13}$: There exists a significant positive relationship between tree cover loss and the core industries' carbon emission levels in India.

Water stress: In an agrarian economy like India, water stress has become a considerable environmental issue. Despite its environmental risks, the issues related to water withdrawal have not been adequately explored in prior studies. The process of water withdrawal involves machinery applications and other tools that require a great deal of energy (Driscoll *et al.*, 2024; Rajan *et al.*, 2020). Considering the energy structure of India, there is always a possibility that the greater energy demands are filled by fossil fuel sources (Energy Institute Statistical Review of World Energy, 2023), which inherit higher risks of carbon emissions. India is still a developing economy that lacks advanced machinery applications and environment-friendly energy components. Therefore, it is expected that higher water stress will increase the emission levels of the core industries too. The core industries are directly responsible for supplying the energy volume and machinery required for the water withdrawal procedures. Therefore, the following alternative hypothesis is formulated:

> $H_{2.14}$: There exists a significant positive relationship between water stress and the core industries' carbon emission levels in India.

Environmental technology: Prior studies have clearly established the importance of research and development activities and innovation in reducing a country's carbon emissions. Opting for alternative eco-friendly energy sources and technological advancements are two of the primary tactics for developing countries to improve their industries' environmental management competence. Therefore, technology upgrades that specifically aim for environmental enhancements are an unavoidable element for polluting countries to become cleaner (Balsalobre-Lorente *et al.*, 2021; Qayyum *et al.*, 2021; Sharma *et al.*, 2021). Developing economies should emphasize technologies that can increase industrial production levels while causing the least environmental harm. India, one of the fastest-growing developing economies, is no exception to such requirements. In order to investigate whether India's environmental technological advancement is helping the core industries curb their emission levels, the following alternative hypothesis is formulated:

> $H_{2.15}$: There exists a significant negative relationship between environmental technology and the core industries' carbon emission levels in India.

Certified Emission Reductions (CER): CER is a mechanism that provides industries with an opportunity to earn material revenues by improving their environmental performance. Usually, industries are hesitant to commit to environmental initiatives, especially in the early growth stages, as they demand financial sacrifices. Initially, industries focus on generating higher revenues by expanding their production levels without considering their environmental consequences. However, the introduction of the CERs is expected to change that attitude of the industries by allowing them to earn back the lost finances that were forgone in the name of the environmental welfare of society. The CER mechanism helps industries trade carbon credits in the market to earn financial rewards, offering the opportunity to materialize their environmental progress. Such incentives are expected to motivate industries to improve their environmental management attributes, leading to low-carbon technologies and innovation (Kukah *et al.*, 2024). Therefore, it is expected that CERs will help reduce emission levels of the Indian core industries. In order to empirically test this proposition, the following alternative hypothesis is formulated:

> ***H*$_{2.16}$**: There exists a significant negative relationship between CER and the core industries' carbon emission levels in India.

5.3. Results and discussion:

5.3.1. Descriptive statistics (Model 2.3):

Table 5.1 provides the descriptive statistics of all the variables considered. The comparison of the mean and median values indicates the degree of the variables' normal distribution. According to the table, the standard deviation of all variables is not very high. The spread volume reflects the distribution levels of all the variables between the maximum and minimum values. Overall, the descriptive statistics reveal satisfactory results for the variables to conduct further statistical analysis.

Table 5.1: Descriptive statistics

	Variable	Mean	Median	Standard Deviation	Minimum	Maximum	Spread
	$lnCO_2$	16.43	18.75	5.57	4.08	21.312	17.232
Economic factors	GDP	4.80	6.09	3.30	-6.73	8,28	15.01
	lnFDI	10.41	10.50	0.47	8.93	11.07	2.14
	lnAGR	19.58	19.96	0.17	19.27	19.86	0.59
	R&D	11.87	12.85	6.39	-0.13	21.91	22.04
Industrial factors	IVA	28.38	30.40	2.21	24.59	31.23	6.64
	EC	8.85	10.15	7.09	-4.51	29.24	33.75
	BANK	58.16	65.15	8.38	-4.31	29.24	33.55
	INDDES	12.29	8.06	2.93	-4.47	95.23	99.7
Demographic factors	lnPOPD	6.07	9.07	0.06	5.96	6.16	0.2
	URB	2.61	2.59	0.700	2.50	2.74	0.24
	POV	71.23	70.51	11.70	2.50	2.74	0.24
	EDU	2.98	2.38	2.88	-1.76	8.40	10.16
Environmental factors	lnTCL	11.52	11.46	0.36	10.85	12.15	1.3
	WS	66.13	68.49	0.611	64.58	66.49	1.91
	ENVTECH	11.56	9.741	5.65	-11.42	9.59	21.01
	lnCER	16.97	16.32	1.45	10.78	17.60	6.82

(Author's calculations)

Correlation matrix: Table 5.2 presents the correlation matrix for pairwise correlation degrees among the independent variables. The table clearly indicates that the correlation degree is higher than 0.80 in a few cases. Due to high multicollinearity, such variables have to be dropped from the regression model to ensure stability and reliability of the empirical results (Gujarati and Porter, 2004). Accordingly, the results for Model 2.3 are reported hereafter.

Table 5.2: Correlation matrix among all variables

	lnCO2	GDP	lnFDI	lnAGR	R&D	IVA	EC	BANK	DES	lnPOPD	URB	POV	EDU	lnTCL	WS	ENVTECH	lnCER
lnCO2	1																
GDP	0.040	1															
lnFDI	0.001	-0.373	1														
lnAGR	0.001	-0.284	0.718	1													
R&D	-0.026	0.011	-0.35	-0.084	1												
IVA	0.005	-0.003	-0.402	-0.875	0.029	1											
EC	0.006	-0.032	-0.26	-0.296	-0.059	0.516	1										
BANK	-0.013	0.132	-0.838	-0.514	0.282	0.162	0.064	1									
DES	0.001	-0.176	0.113	0.211	-0.247	-0.213	-0.384	-0.004	1								
lnPOPD	0.003	-0.069	0.692	0.9892	-0.214	-0.889	-0.328	-0.497	0.154	1							
URB	0.037	0.119	0.606	0.863	-0.368	-0.72	-0.382	-0.473	0.236	0.687	1						
POV	-0.008	0.07	-0.677	-0.988	0.32	0.907	0.341	0.47	-0.163	-0.676	-0.737	1					
EDU	-0.006	-0.11	-0.349	-0.414	-0.047	0.462	0.348	0.264	0.3	-0.434	-0.37	0.401	1				
lnTCL	0.021	-0.044	0.599	0.791	-0.381	-0.799	-0.436	-0.363	0.25	0.815	0.81	-0.619	-0.398	1			
WS	0.027	-0.106	0.745	0.822	-0.332	-0.517	-0.074	-0.674	0.01	0.832	0.788	-0.604	-0.249	0.544	1		
ENVTECH	-0.02	-0.096	-0.376	-0.736	0.06	0.603	0.087	0.516	-0.011	-0.705	-0.669	0.694	0.14	-0.626	-0.623	1	
lnCER	0.015	-0.145	0.757	0.314	-0.381	0.078	-0.159	-0.911	0.017	0.287	0.341	-0.256	-0.201	0.225	0.53	-0.31	1

(Author's calculations)

5.3.2. Regression analysis (Model 2.3):

Table 5.3 presents the results of Model 2.3. The results confirm the positive impact of GDP, EC, lnTCL and WS on the carbon emission levels of the Indian core industries. It implies that these variables lead to greater emission levels in the country. In contrast, the adverse impact by R&D and lnCER are demonstrated, indicating their favourable influence in reducing carbon emissions. Lastly, the coefficient of POV and EDU are found to be non-significant. Detailed discussion of these results is reported in Section 2.3.4.

Table 5.3: DOLS results for the factors of industrial emissions

Variable	Coefficient	Std. error	t-statistics
GDP	0.018*	0.001	-6.469
R&D	-0.001*	0.000	-2.846
EC	0.001*	0.001	2.971
POV	0.134	0.013	1.313
EDU	-0.002	0.001	0.150
lnTCL	0.027*	0.004	6.003
WS	0.098*	0.007	14.122
lnCER	-0.002	0.001	-2.846
Adjusted R^2		0.998	
Breusch-Pagan test		0.260*** (0.613)	
Breusch-Godfrey LM Test		1.500 (0.092)	

(Author's calculations)

***Note**: *, ** and *** represent significance levels at 1%, 5% and 10%, respectively.*

The Adjusted R^2 value of the model is satisfactory, stating that the model captures 99.8 percent variations of the dependent variable. The test-statistic of the Breusch-Pagan test is found to be significant at 10% significance levels, hinting at the possible issue of heteroscedasticity prevailing in the model. However, the DOLS approach is capable of providing robust results by overcoming such statistical issues. The non-significant test-statistic of the Breusch-Godfrey LM test confirms that the model does not suffer from autocorrelation. Lastly, the robustness of the reported results is confirmed by the proceeding empirical results in the current chapter. All the variables from the model are integrated either at (I(0) or I(1), confirming their suitability for DOLS approach (refer to Table 5.9).

Although a few variables had to be dropped in the above regression model due to the statistical confines, the investigation of their impact on the carbon emission levels of the core industries is equally crucial. Their exploration is expected to assist in formulating specific measures to limit environmental pollution from industrial growth. In order to enable such analysis, the potential drivers of emissions are divided into four categories and accordingly, their empirical outcomes are reported in the proceeding section.

5.3.3. Descriptive statistics (Models 2.4 to 2.7)

Correlation matrix: Table 5.4 presents the correlation matrix considering all independent variables of the regression models. The correlation results are reported separately for the different categories of variables. The results confirm that the pairwise correlation degrees of all variables are less than 0.80 in all cases, eliminating that multicollinearity is not an issue in the models. Therefore, the models are suitable for further empirical analyses.

Table 5.4: Correlation matrix

		lnCO_2	**GDP**	**lnFDI**	**lnAGR**	**R&D**
Economic factors	**lnCO_2**	1.000				
	GDP	0.040	1.000			
	lnFDI	0.001	-0.373	1.000		
	lnAGR	0.001	-0.284	0.718	1.000	
	R&D	-0.026	0.011	-0.350	-0.084	1.000
		lnCO_2	**IVA**	**EC**	**BANK**	**IDSN**
Industrial factors	**lnCO_2**	1.000				
	IVA	0.005	1.000			
	EC	0.006	0.516	1.000		
	BANK	-0.013	0.162	0.064	1.000	
	DES	0.001	-0.213	-0.384	-0.004	1.000
		lnCO_2	**lnPOPD**	**URB**	**POV**	**EDU**
Demographic factors	**lnCO_2**	1.000				
	lnPOPD	0.003	1.000			
	URB	0.037	0.687	1.000		
	POV	-0.008	-0.676	-0.737	1.000	
	EDU	-0.006	-0.434	-0.370	0.401	1.000
		lnCO_2	**lnTCL**	**WS**	**ENVTECH**	**lnCER**
Environmental factors	**lnCO_2**	1.000				
	lnTCL	0.021	1.000			
	WS	0.027	0.544	1.000		
	ENVTECH	-0.020	-0.626	-0.623	1.000	
	lnCER	0.015	0.225	0.530	-0.310	1.000

(Author's calculations)

5.3.4. Regression analysis (Models 2.4 to 2.7):

Next, the Breusch-Pegan test and Hausman test are conducted to find the suitable panel data regression approach. The results are presented in the lower segment of Tables 5.5 to 5.8 for the four models undertaken in the study. Firstly, the test-statistic of the Breusch-Pegan test is found to be significant confirming that REM will be a better estimation method over POLS in all four models. However, the test-statistic for the Hausman test is found to be insignificant, which fails to reject the null hypothesis. It indicates the REM will be more appropriate for the empirical analysis in all four models. Accordingly, the results are reported for all four categories of potential driving forces. Thus, in all four models the model suitability tests show similar outcomes.

Economic factors: Table 5.5 presents the empirical results of the economic factors that influence the core industries' carbon emission levels. The results reveal that all the economic factors significantly affect the carbon emission levels of the Indian core industries. *GDP*, *lnFDI*, and *lnAGR* are significant and positively impact CO_2 i.e., cause an increase in carbon emission levels. However, the negative coefficient of *R&D* indicates a reduction in industrial emission levels with a rise in R&D activities.

The positive and significant coefficient of *GDP* implies that India's economic growth has led to greater carbon emission levels by the core industries. Liu and Lai (2021) have shown that economic growth is often expected to increase the emission levels of developing countries that are in early growth stages. Initially, when economic growth occurs, it leads to more industrial setups and encourages higher volumes of production activities, resulting in greater energy demands (Solarin *et al.*, 2017). These factors may hurt the environmental health of a country if they do not have access to environment-friendly resources and technologies. At this stage, production increase becomes the primary motivation for the developing nations to generate more revenues and along the way, the environmental concerns are somewhat overlooked. India is not yet efficient enough to accommodate the massive-scale operations of the firms and industries without causing any adverse effects on the environment, mostly because its energy structure heavily relies on fossil fuels (Das *et al.*, 2011; Vidyarthi, 2013). Such energy sources are one of the major reasons for the increasing emissions in developing or developed economies (Lin *et al.*, 2015; Sarkodie and Strezov, 2019). The results suggest that the Indian economy must enhance energy efficiency, technological upgrades and innovation efforts to overcome the environmental challenges.

The coefficient of *lnFDI* is positively significant, implying that India's FDI inwards has caused emission escalation in the core industries. Such a positive effect is supported by the empirical findings of the previous studies (Adamu *et al.*, 2019; Huang *et al.*, 2022; Sreenu, 2022). The result asserts that the foreign countries' investments in India have led to an unfavourable environmental impact for the latter. Since the economic policy was restructured in 1991, India has welcomed foreign investments to enter its domestic market. However, the results have identified that foreign lands use these investments to exploit India's environmental health. The pollution haven hypothesis states that developed countries transfer highly polluting industries to other developing or less developed economies to reduce pollution levels because the environmental policies are expected to be less stringent in the latter countries (Huang *et al.*, 2022; Jun *et al.*, 2020). Table 5.5 confirms a similar disadvantageous position for India as well. In order to prevent such circumstances, the country should ensure stricter environmental policies in place and demand the follow-up of such policies by foreign countries (Nathaniel *et al.*, 2020). The Government should incentivize FDIs in low-polluting sectors to safeguard the overall environmental health.

The positive and significant effect of *lnAGR* on the core industries' emission levels confirms that India's agricultural productions have been adding to the emission levels of the core industries. Similar results are reported by the prior literature (Doggart *et al.*, 2020; Guan *et al.*, 2023; Menegat *et al.*, 2022). India is an agrarian economy where more than half the population is directly or indirectly associated with the agricultural sector (Ministry of Agriculture and Farmers Welfare, 2022). However, India's agricultural practices are still not considered efficient enough to safeguard the environment. India is burdened with a massive population strength and availing food products for the entire population has become more and more challenging with a continuous rise in the population. As a result, agricultural lands have been expanded for more agricultural production activities. Past studies have noted the harmful effects of such expansions on a country's environment, leading to deforestation, which is the most severe cause of emission escalations (Baumann *et al.*, 2022; Hu *et al.*, 2020). Often, agricultural lands are extended by cutting down trees in forest locations. If proper measures are not taken, such activities can lead to the loss of biodiversity balance. Moreover, various agricultural activities such as applying synthetic fertilizers (Menegat *et al.*, 2022), storing manure (Wang *et al.*, 2022), livestock breeding

(Ullah *et al.*, 2018), machinery usage (Guan *et al.*, 2023), etc., lead to the high emissions. The result arguments for the urgent need for sustainable agricultural production practices in India.

The significant negative coefficient of *R&D* verifies its role in the decreasing emission levels of the Indian core industries. The results can be backed by past empirical studies (Balsalobre-Lorente *et al.*, 2021; Qayyum *et al.*, 2021; Sharma *et al.*, 2021). It indicates that India's commitment towards R&D is helping the nation to control its emission levels. However, the low coefficient value calls for more attention towards the country's R&D sector to have a more prominent favourable impact on improving the environmental quality. More and more technological and energy innovation must be encouraged in India. The dependence on fossil fuels must be reduced to mitigate its possible environmental degrading effects. One of the primary reasons for the controlled pollution levels in developed countries is their emphasis on research. The investment volume in research and development activities of high-income countries is significantly greater than that of low-income countries (Goñi and Maloney, 2017). Such investments lead to access to technological advantages and efficient energy resources in developed countries, which differentiates the fundamental approach of pollution control between developed and developing countries (Majeed *et al.*, 2023; Zhao *et al.*, 2018). India's technological upgrades and innovations should not only be limited to scaling production levels. Instead, the protection and preservation of the ecological balance should be equally prioritized.

Table 5.5: REM results for economic factors

Variable	Coefficient	Robust standard error	z-statistic
GDP	0.011*	0.002	4.91
lnFDI	0.062*	0.214	2.88
lnAGR	0.982*	0.271	3.62
R&D	-0.001**	0.001	-1.97
Constant	-3.350	3.401	-0.99
R^2	0.641		
Wald chi^2 statistic (p-value)	182.92* (0.000)		
Hausman test (p-value)	1.183 (0.757)		
Breusch-Pagan test (p-value)	1035.50* (0.000)		
Breusch-Godfrey LM Test	1.405 (0.122)		
Pesaran CD cross-sectional	1.202 (0.230)		

(Authors' calculations)

*Note: *, ** and *** represent significance at 1%, 5% and 10% levels.*

Thus, the results from Table 5.5 confirm $\boldsymbol{H_{2.1}}$, $\boldsymbol{H_{2.2}}$, $\boldsymbol{H_{2.3}}$ and $\boldsymbol{H_{2.4}}$. Further, the R^2 value signifies that the explanatory variables of the model have captured 64.1% variations in the dependent variable, which is satisfactory. Also, the significant test-statistic of the Wald test at 1% significance level confirms the statistical significance of the overall model considered for the study. Moreover, the test-statistic for the Breusch-Godfrey LM test is insignificant and validates that the model does not suffer from the statistical issues of autocorrelation in the model. The statistical results for the Pesaran CD test also confirm the absence of cross-sectional dependence through its non-significant test-statistic. Thus, the results are found to be reliable and not spurious.

Industrial factors: Table 5.6 reports the results for all industrial factors that can affect the carbon emission levels of the Indian core industries. It is observed that *EC* and *DES* both have significant positive coefficient values, confirming their role in increasing industrial emission levels. In contrast, the negative impacts of *IVA* and *BANK* indicate their contribution towards reducing emission levels of the core industries.

IVA helps decrease the emission levels of the Indian core industries, which is confirmed by its negative and significant coefficient. Previous studies have found a similar advantageous impact of industrialization (Elfaki *et al.*, 2022; Lin *et al.*, 2015; Xu *et al.*, 2022). These studies argue that apart from higher production levels, industrialization also brings in advanced technologies and environment-friendly resources. Industrialization leads to higher environmental awareness among the stakeholders, which pushes firms and industries to adopt eco-friendly practices, resulting in lower emission levels (Elsayih *et al.*, 2021). With growing industrialization, industries begin to generate more revenues over time and the availability of residual resources allows them to focus more on their environmental competence through investments in technologies and innovation. Moreover, modern firms operating in different industries are incentivized to adopt various environmental initiatives in order to achieve market advantages over their competitors. They understand that with the ongoing environmental concerns, such practices add more value to their business from the stakeholders' perspective (Mateo-Márquez *et al.*, 2020; Siddique *et al.*, 2021). Additionally, the environmental regulations also get stricter as industries grow and increase the risk of environmental worsening (Aşici, 2015). As a result, the overall industrial setting moves towards a sustainable movement, confirming advantageous environmental circumstances. Although this finding is contrasting to the general harmful environmental consequences of industrialization, future in-depth analysis on similar lines can offer more concrete arguments in the Indian context.

The positive and significant coefficient of *EC* confirms that Indian industries' energy consumption leads to higher emissions from the core industries. The findings of this study are in line with previous empirical studies (Dogan and Turkekul, 2016; Nathaniel *et al.*, 2020; Sehrawat *et al.*, 2015). High emissions from energy consumption are a burning issue for the entire globe. All the international authorities like the United Nations, IPCC, etc. have been pushing the countries to invest more and more in environment-friendly renewable energy generation and consumption, which is expected to limit the emission levels effectively. However, industries in developing countries like India primarily rely on fossil fuel energy sources (Emir *et al.*, 2024; Munir and Ameer, 2018). Environmentalists always discourage fossil fuel energy sources due to their severe environmental damage and emission levels (Pata and Aydin, 2020; Saboori *et al.*, 2016). As a growing industrialized country, the demand for energy from Indian industries has risen far above the country's renewable energy generation capacity. India is further compelled to utilize more fossil fuel energy sources to fill this gap in electricity energy demand. Also, renewable energy is expected to be more costly, especially in developing countries (Dey *et al.*, 2022; Kumar. J and Majid, 2020). Consequently, industrial energy consumption has led to higher industrial emissions in the country.

The significant negative coefficient value of *BANK* reflects the advantageous role of the financial sector in reducing the core industries' industrial emission levels. In a country, the financial sector should play a vital role in encouraging industries to become more environment-friendly by giving sufficient credits for their R&D activities (Shao *et al.*, 2022; Tamazian *et al.*, 2009). The technology effect highlights that financial development can improve the environment by allocating low-cost funds for eco-friendly projects and technological innovation (Kahia *et al.*, 2017; Kirikkaleli and Adebayo, 2021). Promoting green finance with stricter financial regulations for industries can further help increase its environmental benefits (Wang *et al.*, 2023). The sector should take key measures to monitor the utilization of the credits offered for sustainable projects. An efficient financial structure is expected to help industries lower the cost of raising funds and so that industries can focus more on fulfilling their social and environmental responsibilities, leading to better ecological outcomes.

The coefficient of *DES* is found to be positively significant, asserting that India's industrial design leads to rising emission levels of the country's core industries. It confirms that the industrial design factors of India's core industries are not yet effective in ensuring a better environmental position. Past studies have explored how industrial or product designs can be prepared more efficiently and effectively to benefit the environment (He and Yu, 2021; Zheng *et al.*, 2021). Xu and Qu (2022) empirically demonstrated how sustainable industrial design can help lower carbon emissions in a country. However, in India, focus on industrial design is not prioritized. The results confirm that the quality of the country's industrial designs and innovations has failed to benefit the environment of this massively popularized country. To minimise industrial emissions, sustainable product design must be popularized and followed in India (Amato *et al.*, 2020; Mesa *et al.*, 2019). In modern times, various product designs have been popularized related to the outputs of the core industries such as green concrete designs for benefiting the environmental aspects of the cement industry (Nilimaa, 2023; Suhendro, 2014), controlled-release fertilizer products for the fertilizers industry (Shanmugavel *et al.*, 2023), etc. The dimensions of these sustainable products should be explored by the Indian core industries to look for possibilities for environmental quality improvement.

Table 5.6: REM results for industrial factors

Variable	Coefficient	Robust standard error	z-statistic
IVA	-0.067*	0.019	-3.55
EC	0.004*	0.001	4.06
BANK	-0.004*	0.000	-7.93
DES	0.001*	0.001	2.64
Constant	18.423*	2.611	7.06
R^2		0.597	
Wald chi^2 statistic (p-value)		222.66* (0.000)	
Hausman test (p-value)		1.185 (0.756)	
Breusch-Pagan test (p-value)		1038.46* (0.000)	
Breusch-Godfrey LM Test		1.418 (0.119)	
Pesaran CD cross-sectional		0.307 (0.759)	

(Authors' calculations)

*Note: *, ** and *** represent significance at 1%, 5% and 10% levels.*

The empirical results support $\boldsymbol{H_{2.6}}$ and $\boldsymbol{H_{2.7}}$, while rejecting $\boldsymbol{H_{2.5}}$ and $\boldsymbol{H_{2.8}}$. Table 5.6 confirms that these factors explain 59.7% of the overall variations of the dependent variable. The statistical significance of the overall model is reflected by the significant test-statistic of the Wald test at 1% significance level. Finally, the non-significant test-statistic of the Breusch-Godfrey LM test and the Pesaran CD cross-sectional test indicate that the model is free from autocorrelation and cross-sectional dependence, respectively. Hence, the results of Table 5.6 are confirmed not to be spurious.

Demographic factors: Table 5.7 presents the empirical results of the industrial factors, where the significant effects of all the drivers are confirmed. Among them, only *lnPOP* and *URB* have shown significant positive effects on the core industries' emission levels, implying that they lead to higher emissions. In contrast, the roles of *POV* and *EDU* are non-significant.

The positively significant coefficient value is confirmed for *lnPOPD*, indicating that India's population density has caused a rise in emission levels of the core industries. The nation's rapidly growing population has resulted in the intensification of the agriculture and industrial sectors and unplanned urbanization, creating more pressure on the limited environmental resources (Ray and Ray, 2011). In order to cater for the massive Indian population, industrial operations are compelled to be upscaled, uplifting energy demands from the industrial units to accelerate production levels. In fact, the energy consumption level from households also surges as population density rises, raising the overall energy demands of the nation (Udemba, 2020). Considering the harmful energy structure of India, it is expected that population growth will lead to greater consumption of fossil fuel sources, creating higher chances of carbon emissions from the industries (Danish *et al.*, 2021; Ohlan, 2015). India ranks first in the world in terms of the volume of population in a country (United Nations Department of Economic and Social Affairs, 2024), indicating that environmental pressure is expected to increase even more in the coming years. In order to mitigate such problems, policymakers should put efforts into controlling population growth, restricting migration from outside countries and building quality human capital to achieve environmental harmony.

India's urbanization has been found to increase the levels of carbon emissions of the core industries, confirmed by a positive coefficient value. Urbanization leads to intensified consumption patterns and the concentration of firms and industrial activities in urban areas (Martínez-Zarzoso and Maruotti, 2011). Urbanization enables the movement of the labour force from rural to urban locations, impacting the level of energy usage. Usually, urbanization shifts focus from less energy-intensive agricultural activities to higher energy-intensive industrialized economies (Sadorsky, 2014b). Consequently, greater energy generation and consumption results in higher emission levels of the core industries. Hence, planned urban development should be prioritized by policymakers to balance environmental health and urban expansion in India.

Table 5.7: REM results for demographic factors

Variable	Coefficient	Robust standard error	z-statistic
lnPOPD	2.714*	0.857	3.17
URB	0.540**	0.229	2.35
POV	0.001	0.000	1.54
EDU	0.001	0.002	0.63
Constant	-1.411	3.112	-0.45
R^2		0.661	
Wald chi^2 statistic (p-value)		75.98* (0.000)	
Hausman test (p-value)		1.189 (0.753)	
Breusch-Pagan test (p-value)		1035.29* (0.000)	
Breusch-Godfrey LM Test		1.262 (0.253)	
Pesaran CD cross-sectional		1.476 (0.140)	

(Authors' calculations)

*Note: *, ** and *** represent significance at 1%, 5% and 10% levels.*

However, the coefficients of *POV* and *EDU* are found to be non-significant. Thus, only $H_{2.9}$ and $H_{2.10}$ are confirmed by Table 5.7, whereas $H_{2.11}$ and $H_{2.12}$ are rejected. The R^2 value asserts that the explanatory variables in the model depict 66.1% of the variations of the dependent variable. Besides, the significant test-statistic at 1% significance level of the Wald test confirms the statistical significance of the overall model considered. Also, the test-statistic of the Breusch-Godfrey LM test is found to be non-significant, reflecting that the empirical results do not suffer from issues of autocorrelation. Likewise, the non-significant test-statistic of the Pesaran CD cross-sectional test confirms that the statistical model is free from cross-sectional dependence. Overall, the results are claimed to be reliable and free from spurious objections.

Environmental factors: Table 5.8 documents the empirical outcomes of the environmental factors that impact the emission levels of India's core industries and reports the significant effect of all the variables. Here, *lnTCL* and *WS* have demonstrated positive coefficients, signifying their role in the rising industrial emission levels. On the other hand, *lnCER* and *ENVTECH* are found to be beneficial for mitigating carbon emissions, validated by their adverse coefficient values.

lnTCL documents significant and positive coefficient values, confirming that tree cover loss leads to greater carbon emissions from the core industries. This result is in line with the usual expectation as deforestation and loss of tree cover are recognized as the most fundamental causes of the growing global warming issues. Trees are the most natural and convenient means of enabling carbon storage and carbon removal from the environment (Kumari *et al.*, 2019). In other words, trees are naturally capable of capturing, storing and removing industries' carbon emittance from the atmosphere. As mentioned by the World Bank, forest areas remove approximately 16 billion tonnes of carbon emissions annually, which is roughly around 50 percent of the carbon emissions resulting from fossil fuel burning annually (Benschop, 2023). Therefore, the loss of tree covers leads to the sacrifice of the environment's natural capacity to store and reduce the emission levels of the industries in the surrounding locations. Therefore, policymakers should ensure that whenever industries are expanded into forest locations, the lost tree cover is restored in alternate locations. It is the cheapest and simplest means of minimizing carbon effects in the environment.

Next, the coefficient of *WS* is found to be positively significant confirming the unfavourable impact on the core industries' emission levels. Water stress has become one of the most significant yet unnoticed environmental issues in India that has been adding to the core industries' emission levels. India's huge agricultural sector is involved in a great deal of water extraction processes. The same is applicable for the country's industrial units. The process of water extraction not only leads to water scarcity threatening the survival of all living beings but also causes high emission levels. The agricultural and industrial sectors apply machinery and tools for the process of water extraction, leading to higher levels of energy consumption (Driscoll *et al.*, 2024; Rajan *et al.*, 2020). It has already been established that India's energy structure is extremely harmful to its environment. Likewise, the process of water extraction mostly relies on conventional and high-polluting fossil fuel energy sources, which leads to greater emission levels from the core industries as well. Very few studies have been found in the existing literature that have empirically explored and discussed the environmentally threatening consequences of water stress for a nation (McCarthy *et al.*, 2020; Sowby and Capener, 2022). Further investigation in similar contexts is required for creating a sustainable industrial setting in India.

The negative and significant coefficient of *ENVTEC* has confirmed that focus on the upgradation of environmental technology has led to a reduction of the core industries' emission levels, as expected. It highlights why research development and innovation are so significant for reducing an industry's emission levels (Qayyum *et al.*, 2021). Due to the massively growing population, India's industrial production will undoubtedly continue to rise in the coming years. At the same time, it naturally leads to greater risks of carbon emission levels also. Therefore, focus on environmental technologies has to be the deal-breaker for the Indian industries in reducing their pollution scales. Technologies which can magnify both production scales and environmental efficiency should be prioritized over the sole focus on production growth. It is to be noted that such efforts for innovation must be a continuous determination from the industries (Balsalobre-Lorente *et al.*, 2021; Qayyum *et al.*, 2021; Sharma *et al.*, 2021). Otherwise, even if environmental efficiency is attained at a given production level, that advantageous position will be lost as production will continue to grow. As a result, the scale effect will overlook the technical effect and emissions will continue to increase again. Therefore, policymakers should try to provide the necessary financial and non-financial assistance to the industries to facilitate uninterrupted environmental innovations in India. Such efforts are required to reduce the emission levels of the core industries.

As expected, *lnCER* has documented a negatively significant coefficient value, reflecting its favourable role in reducing emission levels. The certified emission reductions promote the carbon trading scheme, which is expected to become one of the most effective mechanisms for controlling carbon emissions from industries in the near future, especially in India (Rajput *et al.*, 2015). The approval of CERs not only encourages industries to reduce emission levels but also facilitates them to generate financial benefits. Although the carbon credits trading structure became more popular after the Kyoto Protocol Agreement in 1997, it was an effort of a very long term by international organizations (Bhardwaj, 2013). As per the reports published by the Ministry of Statistics and Programme Implementation, Government of India, the nation held 46.5 percent of the total global CERs in 2015. However, that contribution percentage came down to 11.4 percent in 2021. India's government and policymakers should encourage industries to become environmentally more efficient and generate more CERs to reduce industrial emissions. One of the major reasons for decreasing CER attention in India must be the lack of a regulatory foundation for the carbon trading scheme in India (Malav *et al.*, 2015). The absence of a standard exchange market for these instruments has brought an extent of uncertainty among industries because they invest a hefty amount of revenues in generating the CERs. So, they should be assured of some guaranteed trading mechanism to produce their expected revenues.

Table 5.8: REM results for environmental factors

Variable	Coefficient	Robust standard error	z-statistic
lnTCL	0.146***	0.087	1.66
WS	0.224*	0.018	12.33
ENVTECH	-0.001***	0.001	-1.89
lnCER	-0.014**	0.007	-2.03
Constant	0.308	1.425	0.22
R^2		0.676	
Wald chi^2 statistic (p-value)		236.93* (0.000)	
Hausman test (p-value)		0.231 (0.630)	
Breusch-Pagan test (p-value)		835.72* (0.000)	
Breusch-Godfrey LM Test		1.332 (0.197)	
Pesaran CD cross-sectional		1.637 (0.102)	

(Authors' calculations)

*Note: *, ** and *** represent significance at 1%, 5% and 10% levels.*

Hence, the empirical results from Table 5.8 accept $\boldsymbol{H_{2.13}}$, $\boldsymbol{H_{2.14}}$, $\boldsymbol{H_{2.15}}$ and $\boldsymbol{H_{2.16}}$. Further, the R^2 value indicates the model's ability to denote 67.6% of the dependent variable's variations. The significant Wald chi^2 statistics confirm the statistical significance of the overall model considered. Next, the empirical results are free from autocorrelation and cross-sectional dependence, implied by the non-significant test-statistics of the Breusch-Godfrey LM test and the Pesaran CD cross-sectional test, respectively. These test-statistics confirm the reliability of the reported results in Table 5.8.

5.3.3. Robustness check:

Here, the Dynamic Ordinary Least Squares (DOLS) approach is applied using Model 2.1 as a robustness check to the findings of the REM. As a pre-requisite to the DOLS analysis, the variables must be stationary either at I(0) or I(1). The stationarity of the variables is checked using the ADF-Fisher Chi-square and PP-Fisher Chi-square panel unit root test. The results are presented in Table 5.9, which documents that all the variables in the four categories are integrated either at I(0) or I(1). Hence, the panel datasets are suitable for applying the DOLS approach.

Table 5.9: Unit root test results

Variables	ADF- Fisher Chi-square				PP-Fisher Chi-square			
	With intercept		With trend and intercept		With intercept		With trend and intercept	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
lnCO2	15.213	38.717*	12.580	38.145*	31.197**	70.150*	20.731	70.316*
GDP	30.323**	77.988*	18.763	53.346*	72.283*	131.116*	56.064*	100.834*
lnFDI	31.828**	39.005*	30.167**	20.502	96.265*	178.142*	84.049*	112.163*
AGR	2.802	126.330*	67.146*	93.219*	9.097	137.528*	81.421*	104.895*
INV	75.946*	109.820*	53.917*	92.429*	81.422*	151.346*	67.884*	170.396*
IVA	5.235	24.353***	8.406	3.315	1.730	57.616*	40.242*	17.949
EC	12.659	68.159*	21.444	47.076*	27.663**	176.952*	30.337**	176.816*
BANK	25.918***	215.749*	88.944*	172.033*	210.713*	147.365*	147.365*	137.365*
DES	59.417*	90.071*	62.920*	68.723*	25.417***	0.495	130.003*	0.300
lnPOPD	0.011	0.003	0.007	80.906*	0.001	276.403*	0.012	120.700*
URB	12.300	17.551	0.262	120.908*	13.088	49.947*	0.352	51.994*
POV	26.494**	0.047	.001	0.003	114.576*	0.002	0.017	0.002
EDU	19.912	82.327*	23.85***	55.750*	87.945*	147.365*	90.307*	147.365*
lnTCL	8.300	70.431*	9.771	47.778*	13.531	144.246*	24.42***	137.194*
WS	10.890	68.127*	3.528	29.992**	8.952	sss94.146*	21.458	24.250***
ENVTEC	15.743	72.275*	17.525	45.578*	43.716*	208.551*	56.546*	147.408*
CER	69.558*	129.000*	105.723*	84.368*	268.721*	221.460*	14.663*	177.748*

***(**Author's calculations)*

***Note**: *, ** and *** represent significance levels at 1%, 5% and 10%, respectively.*

Table 5.10 presents the results of the DOLS analysis.

Economic factors: The coefficients of *GDP*, *lnFDI,* and *AGR* are found to be significant and positive, while that of *R&D* is significant and negative. This implies that economic growth, FDI and agricultural production lead to an increase in carbon emission, while investment in R&D activities helps curb the emission levels. Thus, the results are similar to those of the REM approach.

Industrial factors: The coefficients of *IVA* and *BANK* are significant and negative, indicating that India's industrialization and financial credits to industries have helped reduce carbon emission levels. On the other hand, *EC* and *INDDES* coefficients are found to be significant and negative. It implies that industrial energy consumption and design factors are increasing carbon emissions from the core industries.

Demographic factors: The coefficients of *POPD* and *URB* are found to have significant and positive effects on the core industries' emissions levels. It establishes that India's population density and urbanization add to the emissions of the core industries, confirming their unfavourable environmental impact. In contrast, the coefficients of EDU and POV are non-significant.

Environmental factors: The coefficients of ENVTECH and lnCER are significant and negative, confirming that environmental technological upgrades and carbon trading mechanisms help reduce carbon emissions. However, lnTCL and WS coefficients are significant and positive. It implies that tree cover loss and water stress levels from industries raise the emission levels of India's emission levels.

Overall, Table 5.10 confirms that the results from Tables 5.5 to 5.8 are robust.

Table 5.10: Robustness test results for the driving factors of industrial emissions

Economic factors			Industrial factors		
Variable	**Coefficient**	**t-statistic**	**Variable**	**Coefficient**	**z-statistic**
GDP	0.007**	2.578	IVA	-0.069*	-28.013
lnFDI	0.084*	6.963	EC	0.004*	5.056
lnAGR	0.003*	19.819	BANK	-0.001*	-18.206
R&D	-0.001**	-2.283	INDDES	0.008***	1.890
R^2	0.979		R^2	0.947	
Adjusted R^2	0.977		Adjusted R^2	0.942	
Demographic factors			**Environmental factors**		
Variable	**Coefficient**	**z-statistic**	**Variable**	**Coefficient**	**z-statistic**
lnPOPD	3.0985*	17.558	lnTCL	0.145*	11.113
URB	0.325**	2.074	WS	0.223*	20.733
POV	-0.000	-0.021	ENVTECH	-0.014*	-3.756
EDU	-0.002	-0.650	lnCER	-0.001**	-2.231
R^2	0.978		R^2	0.440	
Adjusted R^2	0.969		Adjusted R^2	0.382	

(Author's calculations)

***Note**: *, ** and *** represent significance levels at 1%, 5% and 10%, respectively.*

5.4. Chapter summary:

Objective 2 aims to investigate the potential driving factors of carbon emissions in the Indian core industries. In order to identify the drivers of the core industries' emission levels, the present objective categorizes them into economic, industrial, demographic, and environmental factors. The empirical results suggest that among economic factors, economic growth, foreign direct investments and agricultural productions have led to greater emission levels from the core industries, whereas research and development investments are found to help lower the emissions.

Regarding the industrial factors, the industries' energy consumption level and industrial design aspects have added to the increasing carbon emission from the eight core industries. On the other hand, industrialization and the financial sector's credit system have helped combat carbon emissions.

Next, concerning the demographic drivers, only population density and urbanization are found to put environmental pressure on the core industries. In contrast, the roles of poverty and education are found to be non-significant in this case.

Lastly, the empirical results for the environmental factors have depicted unfavourable influences from tree cover loss and industries' water stress, leading to higher carbon emission levels. At the same time, the study establishes that environmental technology upgradation and CER projects can mitigate emission levels. Table 5.11 provides a summarization of the results of all the hypotheses investigated in the present objective.

Table 5.11: Summarization of the results of hypotheses testing

Hypothesis statement	Acceptance/rejection
$H_{2.1}$: There exists a significant positive relationship between economic growth and core industries' carbon emission levels in India.	Accept
$H_{2.2}$: There exists a significant positive relationship between FDI and core industries' carbon emission levels in India.	Accept
$H_{2.3}$: There exists a significant positive relationship between agricultural production and core industries' carbon emission levels in India.	Accept
$H_{2.4}$: There exists a significant negative relationship between R&D and core industries' carbon emission levels in India.	Accept
$H_{2.5}$: There exists a significant positive relationship between industrialization and core industries' carbon emission levels in India.	Reject
$H_{2.6}$: There exists a significant positive relationship between energy consumption and core industries' carbon emission levels in India.	Accept
$H_{2.7}$: There exists a significant negative relationship between financial support and core industries' carbon emission levels in India.	Accept
$H_{2.8}$: There exists a significant negative relationship between industrial design and the core industries' carbon emission levels in India.	Reject
$H_{2.9}$: There exists a significant positive relationship between population density and the core industries' carbon emission levels in India.	Accept
$H_{2.10}$: There exists a significant positive relationship between urbanization and the core industries' carbon emission levels in India.	Accept
$H_{2.11}$: There exists a significant positive relationship between poverty and the core industries' carbon emission levels in India.	Reject
$H_{2.12}$: There exists a significant negative relationship between education and the core industries' carbon emission levels in India.	Reject
$H_{2.13}$: There exists a significant positive relationship between tree cover loss and the core industries' carbon emission levels in India.	Accept
$H_{2.14}$: There exists a significant positive relationship between water stress and the core industries' carbon emission levels in India.	Accept
$H_{2.15}$: There exists a significant negative relationship between environmental technology and the core industries' carbon emission levels in India.	Accept
$H_{2.16}$: There exists a significant negative relationship between CER and the core industries' carbon emission levels in India.	Accept

The findings have added to the existing literature by establishing the impact of some unexplored and relevant variables such as CER, tree cover loss, environmental technology upgradation on carbon emission of industries, in particular for the core industries.