CHAPTER SIX

INDUSTRIAL GROWTH AND ENVIRONMENTAL DEGRADATION IN THE INDIAN CORE INDUSTRIES

Overview: The present chapter conducts empirical analyses to fulfil Objective 3, which investigates the relationship between industrial growth and environmental degradation levels in the Indian core industries, with reference to the inverted U-shaped IEKC hypothesis. In addition, the study attempts to empirically assess the moderating roles of two variables, namely, environmental policy stringency and industrial structure improvement, in the relationship between industrial growth and environmental degradation in the Indian core industries. Furthermore, the turning points of the inverted U-shaped IECK hypothesis are estimated, with and without the moderating effects, to obtain the environmental conditions of the core industries. Lastly, the N-shaped IEKC hypothesis is also empirically tested in the current chapter considering its increasing relevance in modern literature.

6.1. Introduction:

Industrial Growth refers to the expansion and development of the industrial sector in an economy. It is a key driver of economic growth, increasing a nation's production levels. It helps in income and employment generation, infrastructure development, higher exports and fewer imports in an economy. Industrialization encourages economic diversification to ensure better living standards for the people. At the same time, the environmental downturns of industrialization should also receive adequate attention for healthy economic growth. Release of various pollutants and greenhouse gases (GHGs) by industries can prove to be toxic to the environment. Industrial emissions may contain harmful substances like carbon dioxide, sulphur dioxide, nitrogen oxides, particulate matter, etc. All these components can cause severe health issues if emitted on a large scale. Moreover, industries are known for dumping chemicals and other toxic elements into the atmosphere, causing deterioration of land and water quality, and threatening both land and marine ecosystems. All of these industrial pollutants, combined, increase global environmental risks by contributing to ongoing global warming and climate change challenges.

With so much significance at its core, industrialization has become a segment that modern economies cannot afford to ignore even after acknowledging its environmental costs. In that case, sustainable industrialization becomes a desirable solution for an economy to balance economic growth alongside environmental safeguarding. Sustainable industrialization refers to the practices of industrial progression in a way that balances economic growth, social welfare and environmental protection side by side. Modern industrialization is expected to bring technological advancements and the adoption of eco-friendly practices to comprehend the healthy survival of the present world. Given the growing global concerns about environmental degradation, industries bear a significant responsibility to lead nations towards a sustainable future. Researchers have emphasized attaining the economic welfare of the people over economic growth. It is understood that sustainable industrial growth is the prime key to realize this goal. These aspects of industrialization are equally significant for developed to developing countries to create a greener and safer future for all. The IMF reports reveal that around 25-30% of the industrial policies across nations were motivated by climate change mitigation intentions in 2023 (Evenett *et al.*, 2024), signalling the realization of the ongoing weight of sustainable industrialization.

With the growing global warming and climate change concerns, the study of economic growth and its consequential environmental impact has become a quite demanding matter for researchers. In that line, the environmental Kuznets curve (EKC) hypothesis has become one of the most popular approaches for evaluating sustainable economic growth in recent times. Accordingly, the present research work employs the industry-specific EKC (IEKC) hypothesis in the Indian core industries to estimate their environmental impact. The economic significance and the harmful environmental effects of these industries have been highlighted in Chapter 3. The application of the IEKC hypothesis will help estimate the long-term environmental consequences caused by these industries' growth. The hypothesis has a simplified applicability, yet it provides critical policy outcomes for the government and policymakers. Moreover, there are other economic and industrial factors whose presence can alter the relationship between industrial growth and environmental degradation. One such factor is the environmental policy stringency level for the sectors, which may determine the degree of environmental destruction that an industry's progress may invite. Similarly, the economy's energy consumption level and production processes depend mostly on the economy's industrial structure. The overall industrial profile of the nation is expected to direct the environmental effects resulting from the core industries' development. Therefore, the present research work further aims to test the moderating roles of environmental policy stringency and industrial structure improvement in the relationship between the core industries' growth and environmental degradation levels. After testing the IEKC hypothesis, their turning points are estimated to identify in which phase of the hypothesis the core industries currently lie. This estimation will also highlight how the moderating variables can contribute towards their sustainable growth attainment. Considering the contemporary literature, the N-shaped IEKC hypothesis is also investigated in this chapter. The empirical results are believed to contribute significantly to the Indian industry's green movement, providing concentrated direction to policymakers.

6.2. Hypotheses development:

Balancing industrial growth and environmental health has always been a major challenge for any country. As industries grow, they primarily focus on production upscaling to increase the industrial output and generate revenue. The environmental consequences of production intensification are mostly overlooked during the initial growth phases (Alshubiri and Elheddad, 2020; Hua and Boateng, 2015). One of its key reasons is the cost involved in upgrading one's environmental productivity. Usually, achieving environmental efficiency demands financial sacrifices from the industries. Facilitating innovation and technological upgrades requires a lot of resources and time, which the young industries do not wish to forego initially. On the other hand, growing industrial operations increase the country's energy demands, increasing the likelihood of environmental pollution (Opoku and Aluko, 2021; Zafar *et al.*, 2020). In India, energy consumption often leads to higher emission levels due to its poor energy structure, as the majority of its energy demand is fulfilled by conventional, high-polluting fossil fuel sources (Energy Institute Statistical Review of World Energy, 2023).

As and when industries grow, their financial capacity expands, allowing them to make the necessary investments in projects to improve their environmental competence. Industries can allot the required attention to their environmental management attributes once considerable growth levels are achieved (Rai and Rawat, 2022). Focus on renewable energy consumption, innovation, utilization of eco-friendly resources, etc. are a few ways through which industries can attain sustainability in the long run. Gradually, industrial growth enhances the overall environmental quality of the nation (Elfaki *et al.*, 2022; Lin *et al.*, 2015).

Based on the preceding arguments, it is understood that industries' impact on the environment differs based on their stage of growth. With reference to the IEKC hypothesis, this impact is of the nature of an inverted U-shaped. Hence, the current study formulates the following hypothesis.

> $\boldsymbol{H_{3.1}}$: There exists a significant inverted U-shaped relationship between the core industries' growth and their emission levels.

The relationship between industrial growth and environmental degradation is likely to be influenced by the change in government policy or structural change in an economy. For example, strict environmental policies can regulate an industry's emission levels and thereby, protect the environment from high pollution. To penalize those who emit above the prescribed limit, regulatory obligations such as paying penalties and fees can be introduced, whereas well-performed industries may be assisted with favourable credits and subsidies from the government. Such reinforcements push industries to become environmentally more accountable and responsible (Liu *et al.*, 2023; Mateo-Márquez *et al.*, 2020). In a few countries, disclosure of carbon emission levels and other environmental factors of the business has become a regulatory assignment for firms (Boamah, 2022; Jiang and Tang, 2023). Such practices are primarily aimed at promoting sustainability among firms and industries. When environmental policies are robust, even young industries are forced to pay attention to their environmental management ability. Industries focus on eco-friendly resources' innovation and technological advancement in the presence of stricter environmental regulations.

Given this background, it can be assumed that environmental policy stringency can play a moderating role in the relationship between industrial growth and environmental degradation. It is more likely to bring a reduction in carbon emissions from its interaction with industrial growth. Therefore, the following hypothesis is formulated in the study.

> $\boldsymbol{H_{3.2}}$: There exists a significant negative moderating role of environmental policy stringency in the relationship between the core industries' growth and their emission levels.

Likewise, the overall industrial structure of the economy is expected to determine how the industry's growth will impact its environmental conditions (Zhao *et al.*, 2022). Industrial structure improvement is measured by the proportion of the tertiary sector's growth to that of the secondary sector. The tertiary or service sector does not include high-polluting operations. Therefore, the overall energy demand and consumption levels are reduced in that case. As a result, when the tertiary sector experiences more growth than the secondary sector, it reduces the reliance on the core industries as well (which comprise all of India's significant energy industries). Countries are generally advised to emphasize the tertiary or service sector's growth due to its notable advantages over primary and secondary sectors (Zhou *et al.*, 2013). Additionally, the tertiary sector facilitates the quality of the financial institutions and education foundation of the nation. Access to financial services is required for industries to finance their eco-friendly project investments (Tao *et al.*, 2023). Likewise, a proficient educational system spreads awareness and produces skilled human resources to ensure that industries' environmental management improves (Okolo *et al.*, 2023). Such financial and non-financial assistance from the tertiary sector is imperative to reduce the emission levels of the core industries.

Thus, it is expected that industrial structure improvement will negatively moderate the relationship between industrial growth and environmental degradation, and accordingly, the following hypothesis is formulated.

> $\boldsymbol{H_{3.3}}$: There exists a significant negative moderating role of industrial structural improvement in the relationship between the core industries' growth and their emission levels.

6.3. Results and discussion:

6.3.1. Descriptive statistics:

In Table 6.1, the descriptive statistics of all the variables considered in the statistical models of Objective 3 are reported. Here, the mean and median values in all cases do not differ much. The standard deviation of all variables is quite low, except for ICI. However, observing the spread value of ICI, its value of the standard deviation can be considered satisfactory. These results indicate that the variables can be considered to be normally distributed. Overall, Table 6.1 confirms the suitability of these variables for further statistical tests.

Table 6.1: Descriptive statistics

Variable	Mean	Median	Standard Deviation	Minimum	Maximum	Spread
$lnCO_2$	16.43	18.75	5.57	4.08	21.312	17.232
ICI	101.4	98.60	24.98	59.30	168.50	109.20
GDP	4.80	6.09	3.30	-6.73	8,28	15.01
EC	8.85	10.15	7.09	-4.51	29.24	33.75
lnTCL	11.52	11.46	0.36	10.85	12.15	1.30
WS	66.13	68.49	0.611	64.58	66.49	1.91
SECP	1.33	1.320	0.63	0.50	2.19	1.69
INDSTR	2.890	2.793	0.13	2.73	3.24	0.51

(Author's calculations)

Correlation matrix: Table 6.2 shows that the empirical models do not suffer from multicollinearity issues, as the pairwise correlation degree is less than 0.80 in all the cases. Therefore, it is confirmed that the dataset can be proceeded for regression analyses.

Table 6.2: Correlation matrix

	$lnCO_2$	GDP	EC	WS	SECP	INDSTR
$lnCO_2$	1.000					
GDP	0.040	1.000				
EC	0.006	0.032	1.000			
WS	0.027	-0.106	-0.074	1.000		
SECP	0.207	-0.333	-0.394	0.745	1.000	
INDSTR	0.114	-0.113	-0.218	0.273	0.597	1.000

(Author's calculations)

6.3.2. Regression analysis:

A pre-requirement for the application of FMOLS is that all the variables must be integrated at the same level. The results of the test-statistics of the ADF-Fisher chi-square and PP-Fisher chi-square panel unit root test results are reported in Table 6.3. The results confirm that all the variables are stationary at I(1), confirming the suitability of the dataset for FMOLS estimations.

Table 6.3: Unit root test results

Variable	ADF- Fisher Chi-square		PP-Fisher Chi-square	
	First-differenced		First-differenced	
	Intercept	Intercept & trend	Intercept	Intercept & trend
$lnCO_2$	38.717*	38.145*	70.150*	70.316*
ICI	64.228*	50.935*	103.579*	93.548*
GDP	77.988*	53.346*	131.116*	100.834*
EC	68.159*	47.076*	176.952*	176.816*
WS	68.127*	29.992**	194.146*	24.250***
SECP	48.225*	27.765**	116.845*	94.105*
INDSTR	64.391*	32.925*	147.365*	124.342*

(Authors' calculations)

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

The base Model: Table 6.4 provides the results for FMOLS estimation of the base model (Model 3.2). It is observed from the results that the coefficient of *ICI* is significant and positive and that of ICI^2 is significant and negative. This indicates an inverted U-shaped association between industrial growth of the core industries and carbon emission. This supports hypothesis $\boldsymbol{H_1}$, confirming the existence of the traditional IEKC hypothesis in the Indian core industries. The findings for the upward-slopping segment of the IEKC can be explained by the following facts:

i. India's massive population creates an increasing demand for consumer and capital goods making it tough for the country to limit its industrial emissions.
ii. The Indian industries are heavily dependent on fossil fuel energy sources.
iii. India still lacks in the technological aspects compared to the developed countries.

Whereas, the downward-slopping segment of the IEKC can be explained by the following facts:

i. A mature industry has the capacity to generate more revenues to undertake investments for research and development activities.
ii. In the long run, industries realize that to retain stakeholders' support and for market survival, it is essential to adopt environmentally friendly technologies and practices.

Thus, as long as industries continue to cater to the demand by relying on fossil fuel energy and fail to introduce technological innovation, industrial activities are likely to harm the environment. Once this stage is crossed or the threshold point of industrial growth is achieved, industrial activities will no longer pollute the environment. With greater investments in innovation and the adoption of eco-friendly technologies, industries will be able to lower their emission levels.

The control variables GDP, EC and WS are all found to be significant in explaining industrial emissions. The coefficients of GDP, EC and WS are observed to be positive, indicating that economic growth, energy consumption of industries and water stress are all leading to an increase in industrial emissions. The positive effect of GDP confirms that economic growth will add to industrial pollution through greater economic activities consuming fossil fuels. According to the results, EC has shown a significant positive impact on the core industries' carbon emission levels. India is currently in the transformation phase from being an agrarian economy to an industrialized nation. Such a significant economic shift creates greater energy demands for the entire nation. In India, this energy demand is unfortunately met by fossil fuels (Energy Institute Statistical Review of World Energy, 2023). The positive coefficient of WS is found to increase the emission levels of the core industries. India's water stress issues mostly arise from the agricultural sector. India is an agrarian economy which is meeting the demand for food crops for its massive population. In the agriculture sector, water resources are a fundamental requirement. Kousar *et al.* (2021) demonstrated that depletion of water resources can even increase food insecurity in a country. Water pumping from underground sources leads to heavy carbon emissions. Mishra *et al.* (2018) evidenced that water stress from all sectors accounts for two percent of the total carbon emissions in India. Apart from growing water depletion issues, the water pumping process demands high energy consumption due to the application of machinery and other tools (Driscoll *et al.*, 2024; Rajan *et al.*, 2020), leading to the possibility of high carbon emissions.

On the other hand, the control variable SECP is observed to have a negative coefficient, which means it helps in curbing industrial emissions. The coefficient of INDSTR is found to be non-significant. The impact of GDP on carbon emission is positive because growing economic activities fuelled by fossil energy usage will only add to increasing carbon emissions. The negative and significant SECP coefficient confirms the direct impact of

India's sectoral environmental policies in mitigating the carbon emission levels of the core industries, supporting the NIS theory in India's context. As per the existing literature, stringent policy implementation is one of the most effective ways of controlling industrial emissions (Mateo-Márquez *et al.*, 2020). When there are strict environmental laws, the industries become concerned regarding their footprints left on the environment.

Table 6.4: FMOLS results for the inverted U-shaped IEKC Hypothesis

Variable	Coefficient	t-Statistics	Standard Error
ICI	0.037*	7.639	0.005
ICI^2	-0.000*	-6.318	0.000
GDP	0.003**	2.544	0.001
EC	0.001*	3.612	0.000
WS	0.053*	4.658	0.011
SECP	-0.100*	-5.844	0.017
INDSTR	-0.037	-1.087	0.034
Adjusted R^2		0.972	
White's heteroscedasticity test		1.11 (0.292)	
Breusch–Godfrey LM test		122.812*** (0.061)	
Pesaran CD cross-sectional test		1.223 (0.221)	
Durbin test		0.068 (0.794)	
Wu-Hausman test		0.063 (0.802)	

(Author's calculations)

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

Further, the adjusted R^2 value from Table 6.4 reveals that the explanatory variables of the model have depicted 97.2% of the variations in the dependent variable. Next, the non-significant test-statistics of the White's heteroscedasticity test and Pesaran CD cross-sectional test confirm that the model is free from possible issues of heteroscedasticity and cross-sectional dependence, respectively. The test-statistic of the Breusch–Godfrey LM test is significant at 10% significance level, hinting at the presence of autocorrelation in the model. However, the FMOLS approach can overcome such issues to provide robust estimates, as explained earlier (Chowdhury *et al.*, 2022; Farhani and Balsalobre-Lorente, 2020; Zafar *et al.*, 2020). Lastly, the non-significant test-statistics of the Durbin test and Wu-Hausman tests confirm that the empirical model is free from issues of endogeneity and simultaneity biases.

Moderating effect of environmental policy stringency: Table 6.5 presents the results of Model 3.3 incorporating the interaction term *SECP_ICI* in the base model. The findings establish the presence of IEKC in the Indian core industries as in the base model. The coefficient of *ICI* is significant and positive while that of ICI^2 is found to be significant and negative.

Next, the negative and significant coefficient of the interaction term *SECP_ICI* indicates a negative moderating role of environmental policy stringency in the relationship between industrial growth and carbon emission levels. Hence, the empirical results support $\boldsymbol{H_2}$. It implies that implementing strict environmental policies for industries can help reduce the magnitude of consequential emission levels from the core industries' growth. In other words, when industries grow with effective and stringent environmental policies in place, the expected volume of carbon emissions resulting from such industrial growth can be contracted (Liu *et al.*, 2023; Mateo-Márquez *et al.*, 2020). The moderating effect can be explained with the following facts:

i. Strict environmental policies can bind industries to emitting limited quantities of carbon emissions. If emission occurs beyond the permitted limit, industries can be penalized through the mechanisms of carbon tax, environmental fees, etc.
ii. Various government assistance can also be facilitated such as subsidies and credits for industries that notably improve their environmental productivity. For instance, carbon subsidies have become a popular reinforcement in recent times.
iii. Emphasis on the advancement of technologies, energy efficiency and innovation of eco-friendly resources by government authorities compels industries to put in continuous efforts required to improve their environmental competence.
iv. Regular and frequent evaluation of industries' environmental performance helps to take corrective measures as soon as there is a deviation from the expected level of emissions.

Table 6.5: FMOLS results for the moderating role of environmental policy stringency

Variable	Coefficient	t-Statistics	Standard Error
ICI	0.038*	7.233	0.005
ICI^2	-0.000*	-5.784	0.000
SECP_ICI	-0.009*	-4.843	0.002
GDP	0.002***	1.771	0.001
EC	0.001**	3.372	0.000
WS	0.056*	4.759	0.012
INDSTR	-0.046	-1.269	0.036
Adjusted R^2		0.977	
White's heteroscedasticity test		0.87 (0.351)	
Breusch–Godfrey LM test		122.728*** (0.061)	
Pesaran CD cross-sectional test		1.276 (0.202)	
Durbin test		0.049 (0.823)	
Wu-Hausman test		0.0464 (0.829)	

(Author's calculations)

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

The findings on the significance and direction of the effect of the control variables *GDP*, *EC*, *WS* and *INDSTR* are similar to that of the base model (Table 6.4). The adjusted R^2 value is satisfactory for the model, indicating that the explanatory variables are capable of determining 97.7 percent of the variations in the dependent variable. The diagnostic tests confirm that the model does not suffer from heteroscedasticity and cross-sectional dependence, as the test-statistics of White's heteroscedasticity test and Pesaran CD cross-sectional test are non-significant. Although, the test-statistic of the Breusch-Godfrey LM test is significant at 10% significance level, indicating the existence of serial correlation in the model. However, the FMOLS approach is capable of handling such issues and offers robust estimates, as explained earlier (Chowdhury *et al.*, 2022; Farhani and Balsalobre-Lorente, 2020; Zafar *et al.*, 2020). Finally, the regression model is does not suffer from issues of endogeneity and simultaneity bias as confirmed by the non-significant teest-statistics of the Durbin test and the Wu-Hausman tests.

Moderating effect of industrial structure improvement: Table 6.6 reports the empirical results for Model 3.4 with the inclusion of the interaction term *INDSTR_ICI*. Here, the coefficient of *ICI* is found to be positive and significant and that of ICI^2 is negative and significant. Thus, confirming the traditional IEKC hypothesis in the Indian core industries in Model 3.4.

Regarding the moderating effect, the coefficient of the interaction term *INDSTR_ICI* is significant and negative. It indicates the negative moderating role of industrial structure improvement in the relationship between industrial growth and environmental degradation. Thus, $\boldsymbol{H_3}$ is confirmed by the results in Table 6.6. It infers that industrial structure improvement can help reduce the level of carbon emissions from the Indian core industries' growth. Industrial structure improvement prioritizes the growth of the tertiary sector over the secondary sector. An efficient tertiary sector can effectively facilitate sustainable industrial growth. The environmental benefits of industrial structure improvement can be explained based on the following grounds:

i. The tertiary sector consumes less energy than the secondary or primary sectors as the former does not involve heavy industrial operations like the latter ones. As of 2021, the tertiary sector contributed 47.8 percent towards the GDP of India. Given the sizeable proportion of the tertiary sector in India's GDP and its lower industrial operations, environmental risks are lower from the growth of this sector.
ii. The tertiary sector plays a key role in providing the necessary support facilities to improve the core industries' environmental competence. By providing education and training to the workforce, it supplies a skilled workforce that is capable of improving the environmental productivity of industries (Okolo *et al.*, 2023). Even financial institutions help industries improve environmental capability by offering credit, subsidies, and other monetary provisions to afford eco-friendly projects (Tao *et al.*, 2023).
iii. The tertiary sector also includes the quaternary sector, which offers all the intellectual and knowledge-based services. This sub-sector is directly involved in the practices of innovation and R&D accomplishments that are a fundamental requirement for industries to improve their environmental efficiency levels (Tao *et al.*, 2024).
iv. By offering consultancy services, the tertiary sector can guide and advise high-polluting industries to commence effective sustainable practices through eco-friendly investments.

Table 6.6: FMOLS results for the moderating role of industrial structure improvement

Variable	Coefficient	t-Statistics	Standard Error
ICI	0.040*	8.037	0.005
ICI^2	-0.000*	-6.543	0.000
INDSTR_ICI	-0.001**	-2.623	0.000
GDP	0.003*	2.597	0.001
EC	0.001*	3.671	0.000
WS	0.051*	4.537	0.011
SECP	-0.100*	-5.783	0.017
Adjusted R^2		0.967	
White's heteroscedasticity test		1.13 (0.287)	
Breusch–Godfrey LM test		122.918*** (0.060)	
Pesaran CD cross-sectional test		1.345 (0.178)	
Durbin test		0.059 (0.823)	
Wu-Hausman test		0.046 (0.830)	

(Author's calculations)

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

The results on the significance and direction of impact of all control variables *GDP*, *EC*, *WS* and *SECP* are similar to that of the base model (Table 6.4). The adjusted R^2 is also satisfactory, reflecting that 96.7% of the variations in the dependent variable are denoted by the model's explanatory variables. Heteroscedasticity and cross-sectional dependence issues are ruled out by the non-significant test-statistics of the White's heteroscedasticity and the Pesaran CD cross-sectional tests, respectively. Although the model suffers from autocorrelation as indicated by the significant test-statistic of the Breusch–Godfrey LM test, the application of FMOLS can overcome such statistical issues and provide consistent estimates. The absence of endogeneity and simultaneity bias is confirmed by the non-significant test-statistics of the Durbin test and the Wu-Hausman tests.

6.3.3. Robustness check:

To check the consistency and validity of the results of the FMOLS analysis, the present research work applies the Dynamic Ordinary Least Squares (DOLS) approach as a robustness check. As a pre-requisite for DOLS, the variables are required to be stationary either at level, I(0), or at first difference, I(1). This condition is met as shown by the results in Table 6.3 above. Hence, the DOLS estimation is undertaken.

The Base Model: Table 6.7 confirms the truthiness of the inverted U-shaped IEKC hypothesis in the Indian core industries. The coefficient of ICI is significant and positive while that of ICI^2 is significant and negative. Next, the control variables - GDP, EC and WS have all shown significant and positive effects on carbon emissions. In contrast, SECP reveals a significant and negative impact on emission levels and the effect of INDSTR remains non-significant. The adjusted R^2 value of 0.998 is satisfactory, indicating the explanatory variables' capacity to explain the variations in the dependent variable.

Table 6.7: DOLS estimations for the inverted U-shaped IEKC Hypothesis

Variable	Coefficient	t-Statistics	Standard Error
ICI	0.020*	5.549	0.004
ICI^2	-0.000*	-3.598	0.000
GDP	0.008*	5.517	0.001
EC	0.001***	1.930	0.001
WS	0.045**	2.190	0.021
SECP	-0.047*	-2.153	0.022
INDSTR	0.027	-1.021	-0.026
Adjusted R^2		0.998	

(Author's calculations)

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

Moderating effect of environmental policy stringency: In Table 6.8, the coefficient of ICI is found to be significant and positive and the ICI^2 coefficient is significant and negative. Thus, it confirms the existence of the traditional IEKC hypothesis in the core industries. Next, the coefficient of the interaction term SECP_ICI is significant and negative. It implies the negative moderating role of environmental policy stringency in the relationship between industrial growth and environmental degradation. Regarding the control variables, GDP, EC and WS have all shown significant and positive effects on industrial emission levels. On the other hand, the *INDSTR* coefficient is non-significant. The adjusted R^2 value of 0.999 indicates the degree of variations in the dependent variable captured by the explanatory variables, which is satisfactory in this case.

Table 6.8: DOLS estimations for the moderating role of environmental policy stringency

Variable	Coefficient	t-Statistics	Standard Error
ICI	0.024*	7.440	0.003
ICI^2	-0.000*	-1.811	0.000
SECP_ICI	-0.003***	-1.766	0.002
GDP	0.006*	4.858	0.001
EC	0.001**	2.139	0.000
WS	0.043**	2.303	0.019
INDSTR	-0.013	-0.524	0.025
Adjusted R^2		0.999	

(Author's calculations)

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

Moderating effect of industrial structure improvement: The results from Table 6.9 confirm the significant and positive coefficient of ICI, whereas the ICI2 coefficient is significant and negative. Thus, confirming the inverted U-shaped IEKC hypothesis again. The coefficient of the interaction term INDSTR_ICI is significant and negative. It indicates the negative moderating role of industrial structure improvement in the relationship between industrial growth and environmental degradation. Among the control variables, *GDP*, *EC* and *WS* depict significant and positive impact on the core industries' carbon emission levels. Here, SECP has shown a significant and negative impact. The adjusted R^2 value of 0.847 offers a satisfactory level, indicating the explanatory variables' capability to explain the degree of variations in the dependent variable.

Table 6.9: DOLS estimations for the moderating role of industrial structure improvement

Variable	Coefficient	t-Statistics	Standard Error
ICI	0.0413*	13.662	0.003
ICI^2	-0.000*	-11.382	0.000
INDSTR_ICI	-0.001*	-9.111	0.000
GDP	0.001***	1.714	0.001
EC	0.001*	5.570	0.000
WS	0.067*	8.942	0.007
SECP	0.067*	8.942	0.007
Adjusted R^2		0.847	

(Author's calculations)

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

Overall, the results from the DOLS approach validate the reliability and consistency of the FMOLS results with respect to Models 3.2 to 3.4.

6.3.4. Turning point analysis of the IEKC hypotheses:

The findings establish the existence of the inverted U-shaped IEKC in the Indian core industries. In the existing literature, the study of the turning point of the ECK holds important relevance. The turning point identifies the threshold level of economic growth beyond which the harmful environmental effects of growth are minimized. Calculating the turning point in the case of IEKC can also be useful as it will determine the threshold level of industrial growth corresponding to the prevailing IEKC. An empirical approach to estimate this turning point has been discussed by studies like Anser *et al* (2021) and Gill *et al.* (2019). The turning point analysis provides better insights to policymakers to undertake measures for sustainable industrialization.

The estimations of the IEKC turning points are listed in Table 6.10 with respect to the three models discussed above. Also, for the robustness of the findings, the estimated turning points from both FMOLS and DOLS are reported in the table.

Table 6.10: Results of the turning point analysis

Particulars	FMOLS	DOLS
Model 3.2 (Base Model):		
Y*	184.80	179.06
Y**	-	-
Model 3.3 (With SECP_ICI):		
Y*	178.92	181.84
Y**	172.94	178.3
Difference	5.98	3.55
Model 3.4 (With INDSTR_ICI):		
Y*	202.4	206.57
Y**	189.87	187.8
Difference	12.53	18.77

(Author's calculations)

***Note**: Y* indicates turning point without moderating effects, Y** indicates turning point with moderating effect.*

In all three cases, the value of the turning point obtained from FMOLS and DOLS approaches is within a close range, indicating the consistency of the findings. In the base model, the turning point is estimated to be realized for an average *ICI* value in the range of 179.06 to 184.80. It means the industrial growth of the core industries will minimize their adverse impact on the environment once industrial growth reaches an ICI value of 179.06 to 184.80. As per reports, the average *ICI* value of the eight core industries of India is 125.75 in 2021 (Office of Economic Adviser, 2022), which is lower than the estimated value range of the established IEKC's turning point. Thus, the Indian core industries have not yet reached the threshold growth point of the IEKC. It infers that the core industries' growth in India currently lies in the first phase of the IEKC hypothesis, where it continues to cause damage to India's environmental quality through carbon emissions.

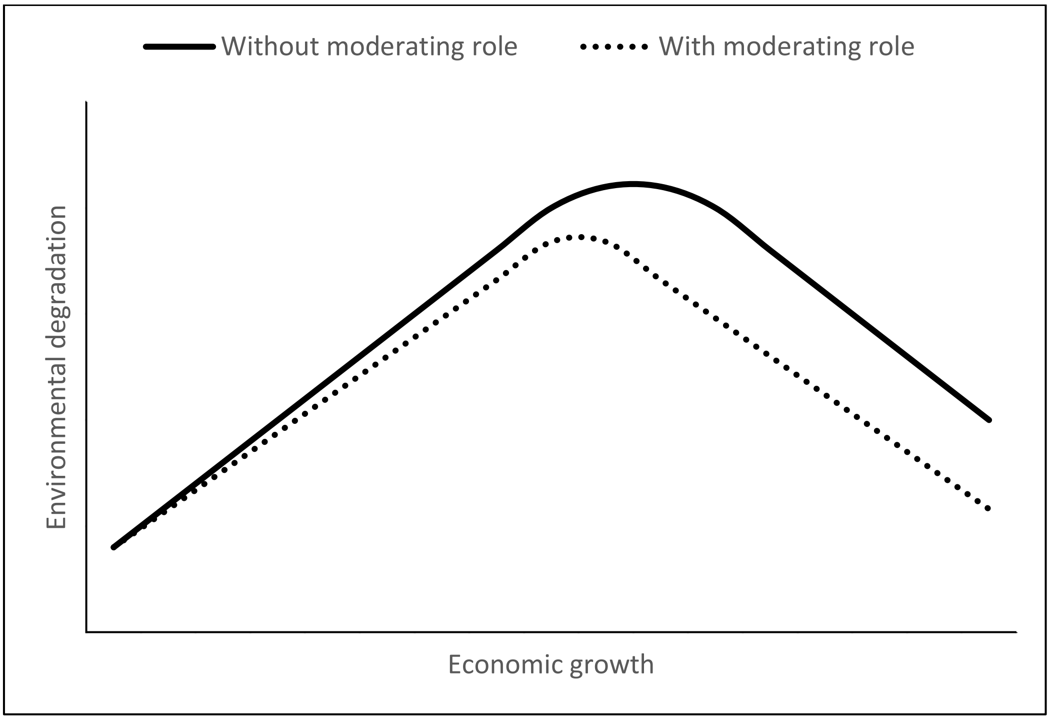
In Model 3.3, Y* indicates the turning point without the moderating term and Y** is the turning point with the moderating term. The formulae for calculating Y* and Y** are given by Equations 3.7 and 3.8 in Chapter 3. The results presented in Table 6.10 reveal a lower range of values of Y** (172.94-178.30) as compared to that of Y* (178.92-181). Clearly, the threshold point is reached at a lower level of ICI or industrial growth when the moderating effect of environmental policy stringency is considered.

Likewise, a lower range value of Y** (189.87-189.87) is found compared to the range value of Y* (202.40-206.57) in Model 3.4. It is an empirical indication that when the moderating effect of industrial structure improvement is included, the turning point of the IEKC is attained at an early stage with a lower ICI value. Thus, it benefits the environmental health.

Policymakers can implement measures promoting stringent environmental policies and improving the country's industrial structure to achieve the turning point early so that the core industries will enter the second growth phase of the IEKC. This second phase is desirable from the environmental perspective because industrial growth contributes towards the ecological welfare of the economy hereafter.

Figure 6.1 provides a graphical representation of how the moderating effect can help achieve the turning point of the inverted U-shaped curve at an earlier and lower state of industrial growth.

Figure 6.1: The inverted U-shaped IEKC curve



(Authors' compilation)

6.3.5. The N-shaped IEKC hypothesis:

The contemporary literature explores the possibility of an N-shaped IEKC hypothesis for industries (Etokakpan *et al.*, 2021; Zhao *et al.*, 2019). Studies have argued that even after industries tackle the environmental hurdles and enter the second phase of the hypothesis (where industrial growth no longer causes environmental degradation), further industrial growth can again distress the environmental balance after the attainment of a second turning point. It means that there could be a third phase of the IEKC, making it an N-shaped curve. Industries if they enter into this third phase will again cause environmental destruction as in the first phase. Therefore, it is essential to estimate whether such a possibility arises for the Indian core industries too. Depending on the empirical outcomes, the situation can be handled suitably and proactively. To investigate the occurrence of the N-shaped IEKC in the Indian core industries, the following hypothesis is constructed:

> $\boldsymbol{H_{3.4}}$: There exists a significant N-shaped relationship between the core industries' growth and their emission levels.

The FMOLS results for Model 3.9 testing the N-shaped IEKC are presented in Table 6.11. Here, the coefficient of ICI is significant and positive, the ICI^2 coefficient is significant and negative, and ICI^3 is found to have a significant and positive coefficient value. Thus, it confirms the validity of an N-shaped IEKC hypothesis in the Indian core industries. The positive coefficient of ICI^3 asserts that after attaining environmental harmony with the inverted U-shaped position, industrial growth will raise the level of industrial emissions again. In other words, environmental damage will take place due to further industrial growth. As and when industrial production increases, the technologies and resources will become obsolete, unable to cater to the environmental demands and expectations for a balanced harmony. Thus, industrial growth loses the advantageous ecological position attained in the second phase of the IEKC hypothesis.

Regarding the control variables, *GDP*, *EC* and *WS* have depicted significant and positive effects on industrial carbon emission. Only SECP shows a significant and negative impact, while the effect of INDSTR is found to be non-significant on carbon emissions. The results are robust with that of the base model. The adjusted R^2 value of 51 percent is found to be satisfactory, indicating the degree of variations explained by the explanatory variables in the empirical model. Next, the diagnostic tests confirm that the model does not suffer from the statistical issues of heteroscedasticity and cross-sectional dependence. It is confirmed by the non-significant test-statistics of the White's heteroscedasticity test and the Pesaran CD cross-sectional test, respectively. However, the serial correlation pertains to the model as indicated by the significant test-statistic of the Breusch–Godfrey LM test. As explained earlier, the FMOLS is capable of statistically overcoming the issue of serial correlation and providing robust outcomes.

Table 6.11: FMOLS results for the N-shaped IEKC

Variable	Coefficient	t-Statistics	Standard Error
ICI	0.312*	6.637	0.047
ICI^2	-0.003*	-6.066	0.001
ICI^3	0.000*	5.662	0.000
GDP	0.001**	2.079	0.000
EC	0.001***	1.944	0.009
WS	0.032*	3.614	0.013
SECP	-0.069*	-5.262	0.001
INDSTR	-0.029	-1.594	0.018
Adjusted R^2		0.510	
White's heteroscedasticity test		40.924 (0.302)	
Breusch–Godfrey LM test		123.569*** (0.055)	
Pesaran CD cross-sectional test		-0.342 (0.732)	
Durbin test		0.445 (0.505)	
Wu-Hausman test		0.417 (0.520)	

(Author's calculations)

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

The DOLS estimations for Model 3.9 are reported in Table 6.12. The coefficient value of ICI is revealed to be significant and positive. Then, the ICI^2 depicts a significant and negative coefficient value, whereas the ICI^3 coefficient is significant and positive. Thus, the results from Table 6.12 confirm the N-shaped IEKC hypothesis in the Indian core industries.

Among the control variables, positive and significant coefficients are found with respect to GDP, EC and WS. On the other hand, SECP shows a significant and negative coefficient value. Lastly, the effect of INDSTR is reported to be non-significant. The adjusted R^2 value is adequate, indicating that the model is capable of capturing a 59.1 percent variation in the dependent variable.

Table 6.12: DOLS results for the N-shaped IEKC

Variable	Coefficient	t-Statistics	Standard Error
ICI	0.232***	1.705	0.136
ICI^2	-0.002***	-1.965	0.001
ICI^3	0.000**	2.310	0.000
GDP	0.038***	1.689	0.023
EC	0.032*	3.466	0.009
WS	0.152***	1.938	0.078
SECP	-0.294***	-1.705	0.172
INDSTR	0.628	1.454	0.432
Adjusted R^2		0.591	

(Author's calculations)

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

Overall, the empirical outcomes of the DOLS approach in Table 6.12 are found to be consistent with the results of FMOLS estimations from Table 6.11.

6.4. Chapter summary:

The present chapter discusses the empirical results for Objective 3, which is to investigate the relationship between the Indian core industries' growth and their environmental degradation, with reference to the IEKC hypothesis. The FMOLS approach is applied for the panel data analysis. The results establish the validity of the inverted U-shaped IEKC hypothesis in the core industries. In this relationship, environmental policy stringency and industrial structure improvement are found to negative moderating effect. Further analysis documents that the turning point of the IEKC is yet to be achieved by the core industries, implying that the industries are still in the first phase of the IEKC hypothesis where industrial growth is proved to be environmentally harmful. Continuing with the investigation, the N-shaped IEKC hypothesis is also examined and confirmed in the Indian core industries. These results provide more significance to the findings of the research work for the government and policymakers. The N-shaped hypothesis asserts that even after attaining the inverted U-shaped position, the industries may enter a third phase that is similar to the first stage. These findings are believed to play a key role in building a sustainable industrial setting in the country. Finally, Table 6.13 provides an overview of the results of the hypotheses testing in the current objective.

Table 6.13: Summarization of the results of hypotheses testing

Hypothesis statement	Acceptance/rejection
$H_{3.1}$: There exists a significant inverted U-shaped relationship between the core industries' growth and their emission levels.	Accept
$H_{3.2}$: There exists a significant negative moderating role of environmental policy stringency in the relationship between the core industries' growth and their emission levels.	Accept
$H_{3.3}$: There exists a significant negative moderating role of industrial structural improvement in the relationship between the core industries' growth and their emission levels.	Accept
$H_{3.4}$: There exists a significant N-shaped relationship between the core industries' growth and their emission levels.	Accept

The findings of this chapter have added to the existing literature by establishing the moderating roles of environmental policy stringency and industrial structure improvement in the relationship between industrial growth and environmental degradation. Additionally, the threshold level analysis for the IEKC and the N-shaped IEKC findings are further contributions to the literature on sustainable industrialization.