CHAPTER TWO

REVIEW OF LITERATURE

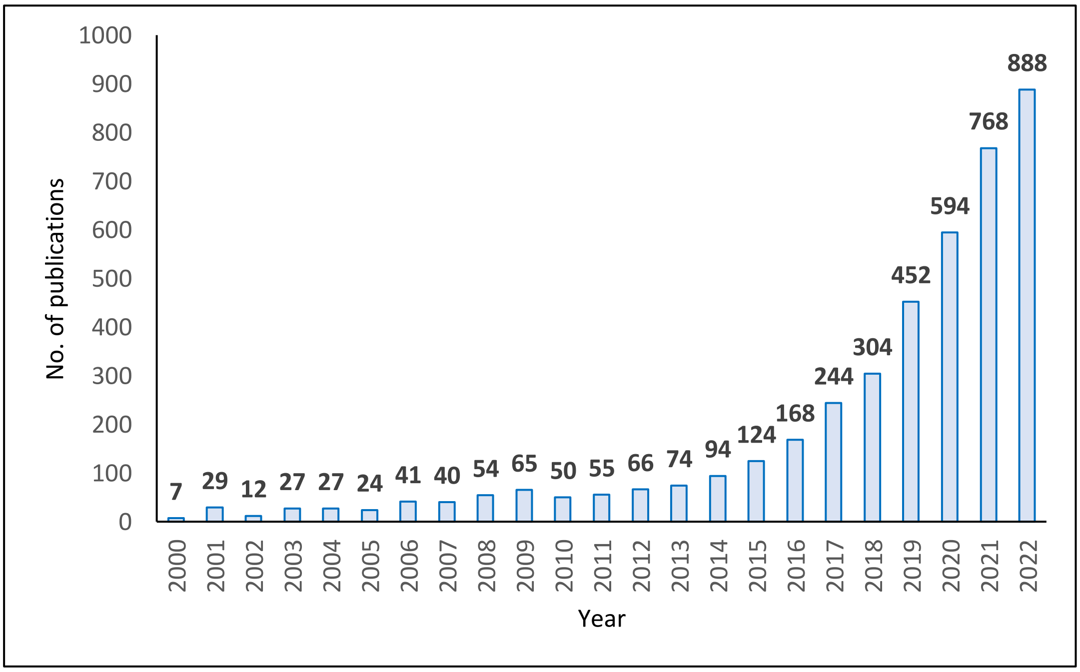
Overview: The present chapter is dedicated to providing an overview of the established literature related to the present research work.

2.1. Introduction:

The present chapter provides a theoretical background of the relationship between industrial growth and environmental degradation, followed by a review of empirical studies in this area. The environmental Kuznets curve (EKC) hypothesis, describing the relationship between economic growth and environmental degradation, lays the theoretical foundation for the study. This hypothesis, as mentioned in previous literature, is applicable to assess the dynamics of the relationship between industrial growth and environmental degradation as well.

Figure 2.1 shows the trend of article publications on the EKC hypothesis worldwide from 2000 to 2022. The rising trend of publication in recent years reveals that studies on the hypothesis are getting significant attention due to its environmental relevance. The data used here is based on the Web of Science database.

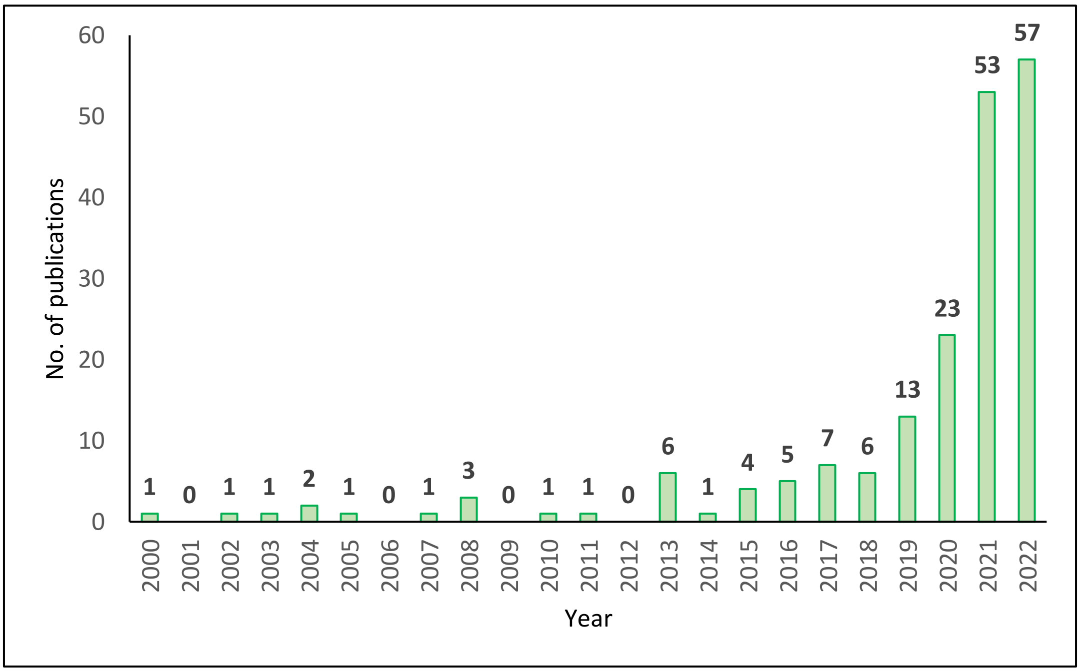
Figure 2.1: Number of publications on the EKC hypothesis worldwide



(Author's compilation)

Figure 2.2 portrays the yearly publication numbers of studies on the EKC hypothesis in the Indian context based on the Web of Science database. The rising number of publications is a clear indication that the relevance of such studies has increased in India over the years.

Figure 2.2: Number of publications on the EKC hypothesis in India



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The present study aims to deliver a detailed discussion of the research articles that have explored the dimensions related to the objectives of the present research work. For ease of understanding, the literature is divided into a few sub-sections to conduct a more focused review. The literature review has helped in the identification of the research gaps for the study.

2.2. The environmental Kuznets curve hypothesis:

2.2.1. Theoretical background:

The environmental Kuznets curve (EKC) hypothesis is one of the most popular approaches for determining the relationship between economic growth and environmental degradation (Grossman and Krueger, 1991, 1995; Kuznets, 1955). It is widely used for the evaluation of sustainable economic growth. The Kuznets curve is named after Simon Kuznets. Initially, Kuznets (Kuznets, 1955) formulated this curve to establish a relationship between economic growth and income inequality. The Kuznets curve hypothesis states that the income inequality of the economy increases when the economy goes through the stages of prosperity in the beginning. However, the relationship changes after the economy reaches a certain growth point. Beyond this point, the inequality in income slowly decreases as the economy continues to grow. As a result, the Kuznets curve represents an inverted U-shaped curve graphically.

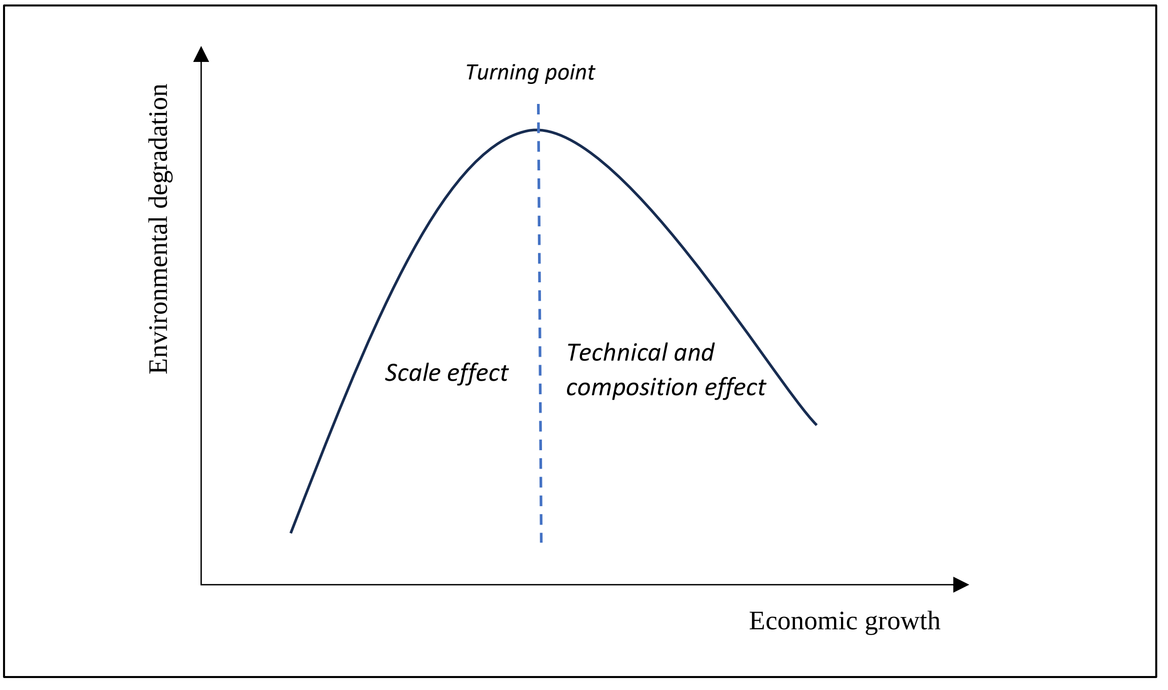
Later, the Kuznets curve hypothesis gained greater significance among environmentalists when Grossman and Krueger (1991, 1995) introduced an ecological approach to the existing hypothesis. They established that economic growth and environmental degradation share a similar inverted U-shaped relationship. Grossman and Krueger (1991) were the first to add the environmental element to the Kuznets curve, whereas Panayotou (1993) was the first to name it the 'environmental Kuznets curve'.

The inverted U-shaped EKC hypothesis describes the expected long-term relationship between economic growth and environmental degradation. The relationship can be divided into two phases. The diagrammatic presentation of the inverted U-shaped EKC is shown in Figure 2.3. The phases of the EKC are described below:

- ***First phase***: As depicted by Figure 2.3, economic growth and environmental degradation share a positive relationship in the first phase of the EKC. In the initial stages of growth, the economy causes environmental deterioration through production growth by overlooking its possible environmental consequences. Greater use of fossil fuels and lack of technological advantages are the main causes of this environmental deterioration. Moreover, the shortage of required financial resources also is a major cause that halts developing countries from technological investments that benefit the environment. In simple words, during the initial development stages, the economy is more focused on production maximization than undertaking measures for the nation's environmental welfare. As a result, the growing production levels lead to harmful environmental consequences, revealing the impact of the Scale Effect in the economy.
- ***Second Phase***: After attaining a threshold growth point, the relationship between economic growth and environmental degradation becomes inverse, as shown in Figure 2.3. When the economy enters the second phase of the EKC hypothesis, it results in environmental quality improvement. With growing environmental concerns, the economy starts putting more effort into overcoming the ongoing ecological issues. The economy reaches a point where financial resources are

generated for taking care of environmental issues through research and development investments. In this phase, the advancement of technologies leads to the Technical Effect that overtakes the Scale Effect from the first phase of the EKC. Apart from the Technical Effect, the Composition Effect also starts assisting the economy towards an eco-friendlier industrial structure. In the Composition Effect, the focus of industrialization efforts is shifted from heavy and energy-intensified industries to light and knowledge-based industries. The composition of the energy structure also changes from fossil fuels to renewable energy sources, achieving significant improvements in the economy's overall environmental quality. Thus, the Technical and Composition Effects enable the attainment of the second phase of the EKC hypothesis, where the economy starts contributing towards the economy's environmental betterment.

Figure 2.3: The inverted U-shaped EKC



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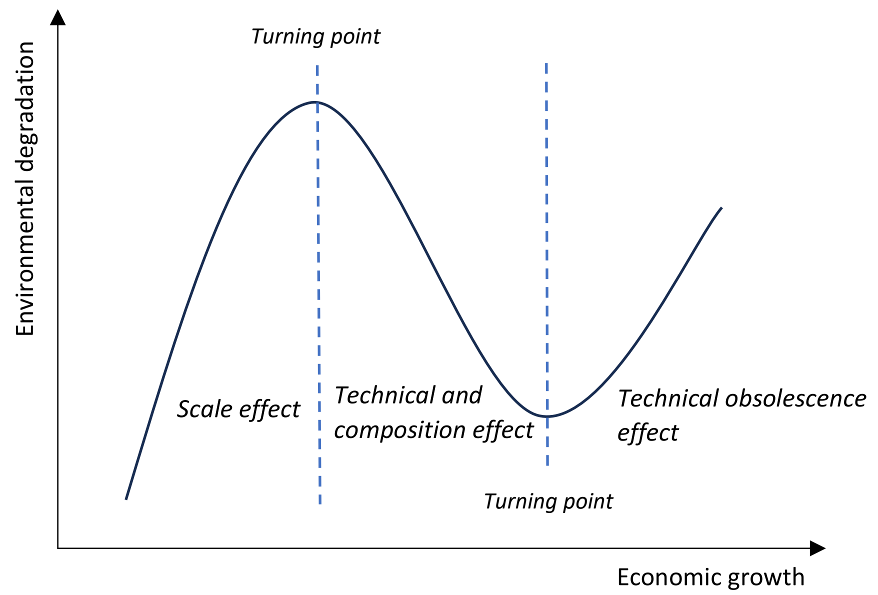
The N-shaped EKC hypothesis: The contemporary literature also explores the N-shaped EKC hypothesis, where an additional phase is expected to occur in the long run.

- ***Third phase***: When the economy continues to grow after attaining the inverted U-shaped position, there comes a second threshold turning point as shown in Figure 2.4. Beyond this point, economic growth and environmental degradation share a positive relationship again, which is similar to the first phase. It is because of the

Technical Obsolescence Effect. In the long run, when production levels continue to rise in the economy, the existing technologies become obsolete and fail to maintain the favourable environmental position of the inverted U-shaped position. As a result, the growing economy starts reflecting its deteriorating effects on the environment again.

Figure 2.4: The N-shaped EKC



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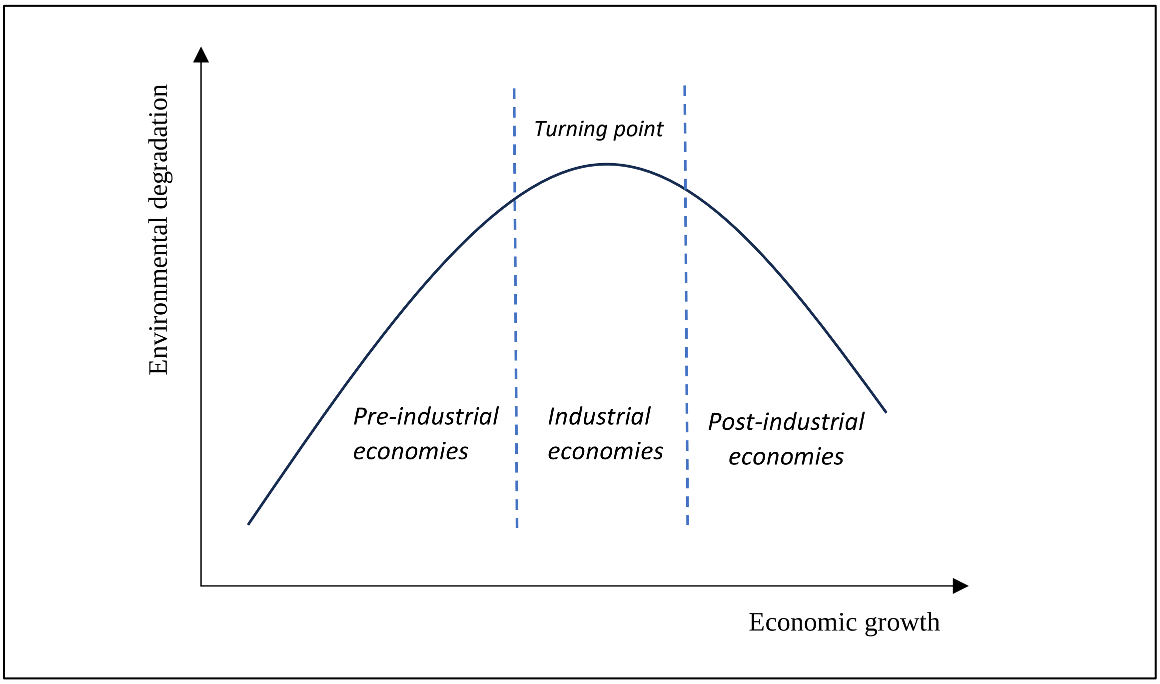
The industry-specific environmental Kuznets curve hypothesis: Application of the EKC hypothesis at an industrial level in existing literature has given rise to the development of the industry-specific environmental Kuznets curve (IEKC) hypothesis. The phases of an IEKC in line with the traditional EKC are explained with respect to Figure 2.5 below:

- ***Pre-industrial economy***: Here, industrial growth is expected to impose a harmful environmental impact as the economy takes a shift from the agricultural sector to the industrial sector. In the initial industrialization period, the economy's prioritization shifted from small and cottage industries to heavy energy-intensive industries, causing detrimental environmental outcomes. In this phase, the curve is rising and quite steep, indicating the rate of increase in environmental degradation is higher.
- ***Industrial economy***: When the industrial economy status is achieved and ample resources are generated, industries attempt to improve their environmental

competence. Industrial growth ensures the availability of financial resources to allow industries to invest in technological advancement and eco-friendly energy innovation. Gradually, the economy also starts re-organizing its industrial structure prioritizing the tertiary sector so that the environmental deteriorating effects from industrial growth can be controlled. Such efforts help them achieve the turning point of the IEKC, where the environmental degrading effects of industrial growth are put to rest.

- ***Post-industrial economy***: After the turning point is achieved, industrialization enters the second phase of the IEKC hypothesis. Continuous industrial efforts with governmental intervention in the post-industrial economies help achieve a favourable sectoral composition to tackle the environmental hindrances of production upscaling. Moreover, technological influences help reduce the pollution levels of the industries, allowing them to recover the overall environmental quality of the economy. In this phase, the IEKC is downward-slopping.

Figure 2.5: The inverted U-shaped IEKC hypothesis



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Further, an N-shaped IEKC hypothesis has also been studied in the existing literature which discusses the possibility of a third phase to the hypothesis. This phase may occur due to the Technical Obsolescence Effect. When industrial production continues to grow, the existing technologies become obsolete to accommodate the production growth without causing ecological ill-effects. Consequently, the sustainable harmony attained through the inverted U-shaped IEKC is lost after the attainment of a second turning point. In this third phase, industrial growth once again starts deteriorating the environmental quality. In that case, the N-shaped IEKC hypothesis is observed between industrial growth and environmental degradation.

2.2.2. Review of empirical studies:

The EKC hypothesis: Over the years, a plethora of studies have focused on investigating the EKC hypothesis and found mixed findings. While some studies have confirmed its presence, others have denied its existence. Its validity varies from country to country, depending on which growth stage they are going through (Bader and Ganguli, 2019; Leal and Marques, 2022).

Hua and Boateng (2015) investigated the EKC with a panel data sample of 167 countries. The empirical results of the study found evidence for the inverted U-shaped curve. Nasreen and Anwar (2015) validated the EKC hypothesis in terms of countries with different income levels. The study has accepted its true presence in all the observed cases. However, the authors stated that the curve was more apparent in the high-income country panel compared to the middle and low-income countries. Asumadu-Sarkodie and Owusu (2017b) found support for the validity of the EKC hypothesis in Rwanda. The study signifies the role of sustainable industrial practices in improving the country’s overall environmental quality, which consists of utilizing eco-friendly raw materials, technologies and energy sources. Alshubiri and Elheddad (2020) concluded that foreign finance and economic growth show an inverted U-shaped curve as suggested by the EKC hypothesis. Akadırı *et al.* (2021) validated the EKC hypothesis in the context of BRICS countries (Brazil, Russia, India, China and South Africa). The study also reveals that the utilization of fossil fuel energies has degraded the overall environmental quality of these countries. Adeel-Farooq et al. (2021) proved that the EKC hypothesis is true and valid in the context of the ASEAN countries. In the study, the EKC was established between economic growth and the emission of methane (CH_4). Koshta et al. (2021) validated the EKC hypothesis with a panel of selected emerging countries. The study highlighted the role of promoting energy conservation policy in order to achieve ecological harmony in developing countries.

However, several studies have challenged the existence of the inverted U-shaped EKC in various geographical locations. Dogan and Turkekul (2016) found a U-shaped EKC between gross domestic product (GDP) growth and carbon emissions in the US contrary to the traditional EKC hypothesis. The study suggests that an efficient energy structure helps curb the CO_2 emission levels of a country. Pata and Aydin (2020) concluded that the EKC hypothesis is not applicable in the context of Brazil, China, India, Norway, Canada and the US. The hypothesis was tested for the relationship between the respective countries' ecological footprint and economic growth. Pata and Caglar (2021) revealed the non-existence of the EKC hypothesis in terms of the relationship between environmental pollutants and income levels in China. Both carbon emissions and ecological footprints were considered for measuring environmental degradation in the study. Arnaut and Lidman (2021) found evidence for a U-shaped EKC in Greenland, rejecting the traditional EKC hypothesis. The study reveals that after industrialization began in the country, the carbon emission levels increased significantly, causing higher environmental degradation levels. Minlah et al. (2021) investigated the N-shaped EKC hypothesis in Ghana. For environmental degradation and economic growth, deforestation and GDP of the country, respectively. However, the results suggested that an inverted N-shaped EKC is applicable in the context of Ghana instead.

The EKC hypothesis in the Indian context: A few empirical studies have attempted to validate the EKC hypothesis in the Indian context. Several studies have been conducted by researchers and have found different results. Managi and Ranjan (2008) established the inverted U-shaped EKC hypothesis between the income of the Indian states and their environmental productivity. It was empirically found that the developed states can reduce environmental deterioration more efficiently at a faster rate than the low-income level states. Kanjilal and Ghosh (2013) confirmed the inverted U-shaped EKC hypothesis, emphasizing the need for investment in the energy structure of the nation. Sehrawat et al. (2015) found evidence for the EKC hypothesis between financial development and environmental degradation in India. A similar inverted U-shaped EKC hypothesis is established in India by Solarin et al. (2017). Sinha & Shahbaz (2018) found that the EKC hypothesis was present in the Indian context. The study highlights that with time, the Government can take measures to flatten the EKC and achieve economic growth without degrading the environment in the long run. Rana and Sharma (2019) also validated the inverted U-shaped EKC hypothesis in India. They evidenced that the import of pollution-intensive manufactured goods is a primary cause of emission increase in India. Danish et al. (2021) evidenced an inverted U-shaped EKC hypothesis, arguing that a transition towards nuclear energy consumption can significantly contribute towards India's sustainable development.

However, some studies have contradictory results. Alam et al. (2016) empirically denied the existence of the EKC for CO_2 emissions in India. Asumadu-Sarkodie and Yadav (2019) discovered a U-shaped curve as opposed to the traditional EKC hypothesis. They state that the industrialized economy of India is not environmentally sound with a considerable presence of high energy and carbon-intensive industries. Adamu et al. (2019) also reveal that the EKC hypothesis is invalid in the Indian context. Villanthenkodath et al. (2021) rejected the conventional EKC hypothesis and found a U-shaped relationship between economic growth and carbon emissions instead. The study highlights that the chemical and heavy industries are responsible for high carbon emissions in the country. Similarly, Itoo and Ali (2023) demonstrated the non-applicability of the EKC hypothesis in India.

Further, the N-shaped EKC hypothesis has also been investigated by limited studies in the Indian context. Pal and Mitra (2017) found an N-shaped EKC hypothesis for India, urging the reorganization of energy policies in the country. A transition towards renewable energy generation is essential for sustainable economic growth in the long run. Pandey and Mishra (2021) investigated the EKC in India with respect to sulphur dioxide and nitrogen dioxide. Their empirical results have confirmed the N-shaped EKC in both cases, indicating a sustainable structural change in the country. Rej and Nag (2022) demonstrated evidence for a valid N-shaped EKC in India between carbon emission and economic growth. They have highlighted the significance of renewable energy consumption in achieving sustainability in India. Similarly, Nica et al. (2024) supported the N-shaped IEKC hypothesis in India, emphasizing the favourable role of renewable energy and access to electricity on the environment. Farooq et al. (2024) evidenced the N-shaped EKC in the Indian context. They stated that India is currently going through the initial phase where economic growth causes environmental degradation. Therefore, measures must be implemented to facilitate faster and sustainable growth of the economy to assist the overall sustainable growth of the country.

The IEKC hypothesis: Based on these arguments, several studies have focused on the exploration of the industry-specific EKC (IEKC) hypothesis, concentrating on the sustainable assessment of particular industries. The investigation of the IEKC hypothesis can specifically reveal the expected environmental consequences of an industry's growth.

The exploration of this hypothesis can potentially benefit the overall economy as well by enabling sustainable industrial growth. However, very few studies have conducted empirical studies to investigate the IEKC hypothesis. Most studies have focused on the exploration of the EKC hypothesis on economic levels in the contexts of different countries. The findings from these studies fail to provide a focused overview of industries' long-term environmental effects in particular.

Table 2.1 shows the review of a few articles from the Web of Science database that have attempted to empirically test the IEKC hypothesis.

Table 2.1: Reviews of articles on the IEKC hypothesis

Sl no.	Author(s), (Year)	Region/ Country	Industry (Years studied)	Variables used	Findings
1	Liu et al. (2009)	China	Cement Manufacturing (1969 to 2003)	CO_2 emissions from the cement industry, End year population, GDP per capita.	The STIRPAT model confirms the existence of the EKC hypothesis.
2	Fujii and Managi (2013)	OECD countries	Manufacturing industry and construction; Food and Tabaco; Wood and wood products; Chemical; Paper, pulp and printing; Non-metallic minerals; Steel and Metal; Machinery; Transport equipment; Construction (1970 to 2005)	CO_2 per capita (sector-wise), GDP per capita, energy efficiency, share of each industry in GDP.	The panel regression analysis in the study confirms the existence of the EKC only in the wood and wood products industry; the paper, pulp, and printing industry and the construction industry
3	Xu and Lin, (2016)	30 provinces in China	Manufacturing (2000 to 2013)	Total CO_2 emissions in the manufacturing industry, population size, real per capita GDP, energy	The nonparametric additive regression model of the study confirms a valid Inverted U-shaped EKC between economic

				consumption, urbanization industrialization, energy structure.	development and CO_2 emission levels of China's manufacturing industry. However, the CO_2 emission levels have shown mixed results of the EKC with the rest of the explanatory variables.
4	Fujii and Managi (2016)	39 countries	14 industries (1995 to 2009)	Per capita emissions of eight environmental air pollutants, GDP per capita, high pollution intensity fossil fuel dependency, energy efficiency, skilled labor, industrial value share, country's political situation.	The EKC hypothesis is confirmed by the panel regression test results at the country level and collective industrial sector level. However, the hypothesis was denied in 10 industries in the case of all eight pollutant emissions.
5	Xu and Lin (2017)	30 provinces in China	Iron and steel (2000 to 2013)	CO_2 emissions in China's iron and steel industry, population size, real per capita GDP, energy efficiency, urbanization level, industrialization, energy consumption structure.	The nonparametric additive regression model of the study confirms a valid Inverted U-shaped EKC between economic advancement and levels of CO_2 emission in China's iron and steel industry. However, the CO_2 emission levels have mixed

					results for EKC with the rest of the explanatory variables.
6	Wang et al. (2017)	China	Mining, Manufacturing, Electricity and heat production (2000 to 2013)	Carbon emissions per capita (sector-wise), GDP per capita, energy intensity, urbanization level.	The EKC hypothesis is confirmed by the STIRPAT model only in the case of the electricity and heat production sector, between income and carbon emission levels. On the other hand, the manufacturing industry portrays the inverted U-shaped EKC in relation to urbanization and carbon emission levels.
7	Bella (2018)	France	Tourism (1995 to 2014)	Per capita carbon dioxide emissions from transport, gross domestic product, total number of tourist arrivals.	The existence of the EKC is confirmed by the VECM long-run and short-run test results.
8	Ru et al. (2018)	199 countries	power, industry, residential and transportation sector (1980 to 2014)	Long-term growth rate of emissions per capita, long-term growth rate of GDP per capita.	The integrated assessment model confirms mixed findings while testing the truthiness of the EKC

					hypothesis in the observed sectors.
9	Song and Wang (2018)	China	Power generation industry (2006 to 2011)	Calculated environmental inefficiency score, per capita GDP, Education degree, Population density	The study confirms a valid EKC using Tobit regression analysis.
10	Zhao et al. (2019)	China	Textile (2001 to 2012)	Water footprint of China's textile industry, output value of China's textile industry.	The study has found mixed conclusions about the EKC's validity. The blue water footprint model of China's textile industry finds an inverted U-shaped curve, the original grey water footprint shows an inverted N-shaped curve and residual grey water depicts an N-shaped curve.
11	Erdogan et al. (2020)	Top 10 air passenger-carrier countries (China, Germany, India, Ireland, Japan, Turkey, United Kingdom and United State	Transport (Airline and Railway) (1995 to 2014)	Carbon dioxide emissions per capita, real GDP per capita, airways transport (passenger carried), railway transport (passenger carried), fossil fuel energy consumption, urban population.	The FMOLS and MG indicate the existence of the EKC hypothesis in the study.

12	Ahmad et al. (2020)	30 Chinese provinces	Financial development and construction industry (2001 to 2016)	Carbon dioxide emissions per capita, GDP per capita, Financial development per capita, added value of construction per capita, Energy use per capita.	The study applies the Pedroni-based panel cointegration test and finds that financial development-augmented and construction industry-augmented EKC are valid in the observed provinces.
13	Du et al. (2020)	Five low-carbon pilot provinces in China	Construction (2005 to 2014)	Construction industry carbon emissions per capita, construction industry output values per capita.	The regression analysis reports mixed results regarding the confirmation of the traditional EKC hypothesis.
14	Chan and Wong (2020)	30 provinces in China	Tourism (1997 to 2015)	Per capita carbon dioxide inventory level, real gross regional product per capita, the tourism variable (the total number of tourist arrivals and real total revenue in the tourism industry).	The panel data regression results confirm the EKC in the observed provinces.
15	Elsalih et al. (2020)	28 oil-producing countries	Crude oil industry (2002 to 2014)	CO_2 emission, the comparative advantage of crude oil, environmental performance index, institutional quality, daily average of crude oil, domestic demand for crude oil, proven reserve, gross domestic product.	The EKC hypothesis is validated using two steps system GMM estimation.

16	Huang et al. (2020)	Five provinces of Northwest China	Agriculture (1993 to 2017)	Intensity value of agricultural carbon emission, intensity value of agrarian economy.	The study finds an inverted N-shaped curve through regression analysis.
17	Anser et al. (2021)	26 European countries	Agriculture (2000 to 2017)	Agriculture tractor, high-technology exports, ICT goods exports, research and development expenditures, FDI inflows, trade openness, carbon dioxide emission intensity, telephone subscriptions, mobile subscriptions, internet penetration, GDP per capita, industry value-added.	The study confirms through panel regression that an 'agriculture technology Kuznets curve' is valid in the observed countries.
18	Hassan et al. (2021)	21 OECD nations	Aviation (1980 to 2018)	CO_2 emissions (metric tonnes per capita), GDP per capita (constant 2010 US$), Energy consumption (kg of oil equivalent per capita), Trade (% of GDP), Air transport, freight (million tonne-km), Air transport, registered carrier departures worldwide.	Through the panel generalized method of moments, the study reveals mixed results in the context of aviation cargo and aviation passengers' industries.
19	Balsalobre-Lorente et al. (2021)	Five European Union (EU-5) nations	International tourism (1990 to 2015)	Per capita carbon emission, per capita income level, net inflows foreign direct investment, renewable energy production, public budget in energy innovations, air transport.	The FMOLS analysis of the study supports an existing EKC in the international tourism industry of the observed countries.

20	Rashdan et al. (2021)	14 countries	Capture fisheries (1992 to 2016)	Capture fisheries production, per capita gross domestic product, industry value-added, exports of goods and service, imports of goods and services, domestic credit provided to the private sector.	The study confirms an N-shaped relationship between the variables using the panel dynamic ordinary least square method.
21	Liu et al. (2021)	25 counties/districts in the Three Gorges Reservoir Region	Agriculture (2002 to 2017)	Agricultural chemical inputs, GDP per capita, the agricultural population, cultivated land area, agricultural investment, urban-rural income disparity, proportion of primary industry (agriculture).	The spatial panel regression analysis used in the study confirms the presence of the EKC hypothesis.
22	Lv et al. (2021)	China	Manufacturing (1995 to 2017)	CO_2 emissions, value added of the manufacturing industry.	The study finds a valid EKC in China's manufacturing industry by integrating EKC with the decoupling method.
23	Fatai Adedoyin et al. (2021)	26 EU member states	Tourism (1995 to 2018)	Carbon dioxide emission (Million tons of carbon dioxide), GDP per capita, Primary energy consumption, international tourist arrivals, Economic Complexity Index.	The study conducts panel regression analysis and finds mixed findings regarding the validity of EKC.

24	Wu et al. (2022)	China	Primary, Secondary and Tertiary (1990 to 2015)	GHG emissions per capita of the sector, value added of sector, single sector's intermediate goods in all sectors, single sector's intermediate goods exported to all sectors in the USA, single sector's final goods exported to consumers in the USA, energy intensity of sector, energy structure of sector.	The results of panel corrected standard error method verify the EKC hypothesis only in the tertiary sector of China. The tertiary sector emits the least amount of pollutants compared to the other two industries.
25	Htike et al. (2022)	86 developing and developed countries	Electricity and heat production; manufacturing industries and construction; residential; transport; agriculture, forestry, and fishing; commercial and public services; and other energy industry own use (1990 to 2015)	Sector-wise CO_2 emissions, income level, Total final energy consumption, Renewable energy share in total, Total natural resource rent, Trade openness.	The PMG-ARDL models used in the study empirically confirm the EKC hypothesis in electricity and heat production, commercial and public services, and other energy industries.

26	Taşdemir (2022)	54 countries	manufacturing, industry, and service sector (1971 to 2017)	CO_2 emissions per tones per capita, real GDP per capita, share of manufacturing sector value added in GDP, share of industrial sector value added in GDP, share of service sector value added in GDP.	The panel smooth transition regression (PSTR) analysis denies the existence of the traditional inverted U-shaped EKC.
27	Shao et al. (2022)	30 countries	Iron and steel (1990 to 2018)	CO_2 emissions of the industry, financial development index, financial development, urbanization, trade openness of the industry.	The comprehensive panel data analysis confirms the existence of the hypothesis.
28	Murshed et al. (2022)	Argentina	Energy; manufacturing and industry; residential and commercial buildings; transportation sectors (1971 to 2014)	Annual sectorial fossil fuel consumption-based CO_2, emissions per capita figures, share of total electricity output generated using renewable sources, trade globalization index, real GDP per capita, share of domestic credit extended to the private sector by banks, urbanization rate, energy intensity level.	The ARDL methodology has confirmed the EKC for all the four sectors

(Author's compilation)

In Table 2.1, among the 28 articles reviewed on the IEKC, 26 of them were published on or after 2016. It proves the growing relevance of the IEKC hypothesis due to today's environmental circumstances. Most of the articles mentioned in Table 2.1 have used industry-level measures for environmental degradation. However, they have considered economy-specific explanatory variables for testing the IEKC. The studies using economy-level variables fail to provide accurate and precise estimations of the IEKC hypothesis, which applies to industrial growth and environmental degradation in particular. Similarly, no study has been found that has investigated the IEKC hypothesis in the context of the Indian core industries. Further, with the growing industrial sector in the nation, there arises a possibility for the existence of the N-shaped IEKC hypothesis, especially with respect to the core industries. However, the empirical investigation of the N-shaped IEKC for the Indian industries is also non-existent in the prevailing literature. Considering their long-term pertinence, the present study attempts to fill such research gaps by exploring the validity of both the inverted U-shaped and the N-shaped IEKC hypotheses in the Indian core industries. This exploration is expected to offer valuable insights into building a long-term sustainable industrial setting.

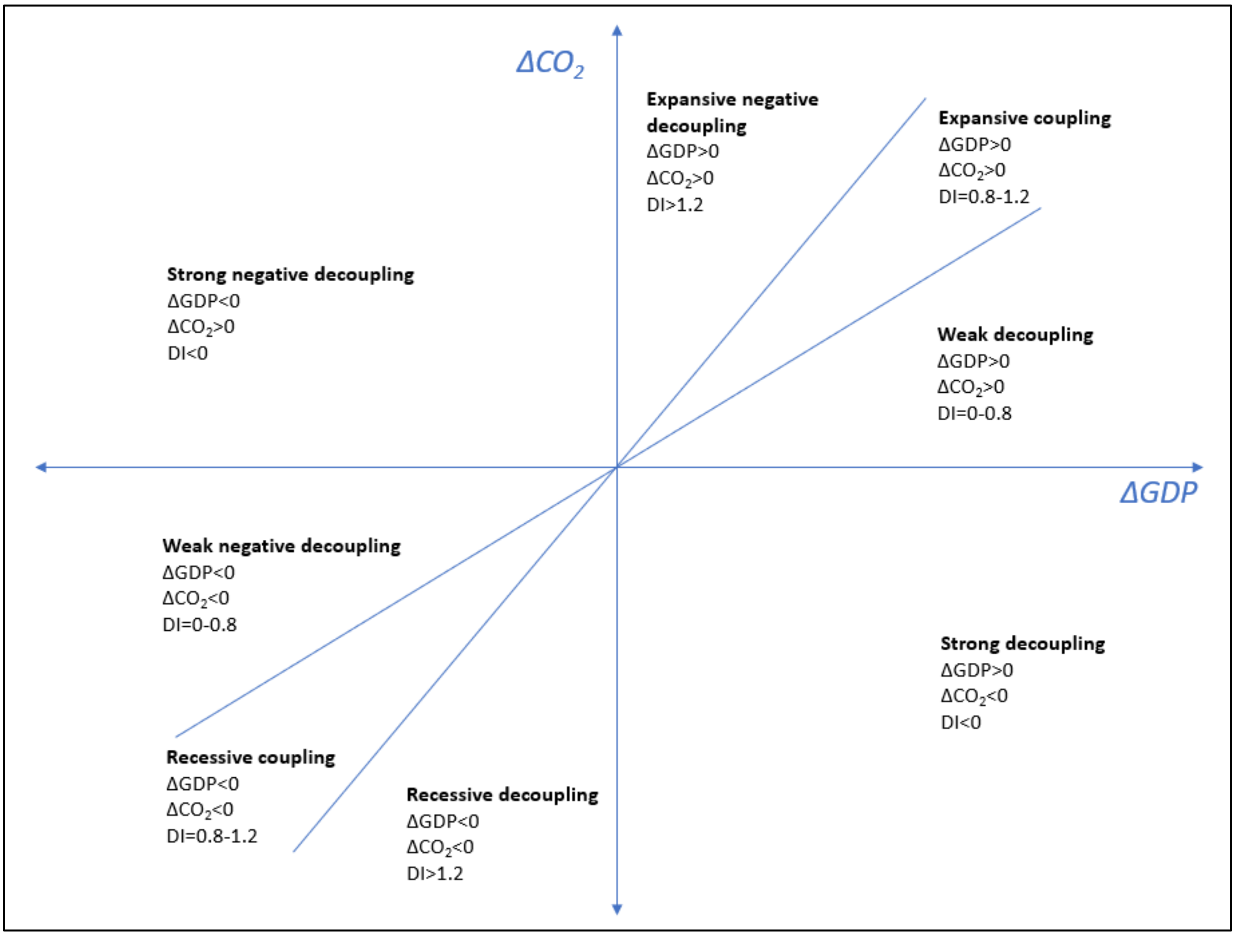
2.3. Decoupling index:

2.3.1. Theoretical background:

The application of the concept of "decoupling" in environmental studies was popularized by the Organization for Economic Cooperation and Development (OECD). OECD used the term "decoupling" to indicate the state of the relationship between economic growth and the pressure put on the environment when they both lose synchronization at a particular point in time. OECD divided this relationship into relative decoupling and absolute decoupling. Relative decoupling occurs when environmental degradation increases at a lower rate than economic growth. On the other hand, if the pressure on the environment declines with an increasing rate of economic growth, it is called absolute decoupling (OECD, 2002). Later on, the decoupling approach was adopted by many researchers to study the responsiveness of the environment toward one's economic growth. Among them, the works of Vehmas et al. (2003) and Tapio (2005) received noteworthy attention. Vehmas et al. (2003) established a few additional degrees of elasticity of environmental stress (ES) towards economic growth (Gross Domestic Product, in this case). Six degrees of environmental responsiveness (ES/GDP) were established depending on the rate of re-linking and de-linking relationship of environmental stress indicators towards GDP. While the OECD framework (2002) and Vehmas et al. (2003)

suggested two and six degrees of decoupling, respectively, Tapio (2005) made a few more significant contribution to this approach by suggesting eight elasticity degrees of carbon emission levels with a more dynamic approach. Figure 2.6 provides the graphical representation of Tapio's eight elasticity degrees with respect to economic growth (*GDP*) and carbon emission levels (CO_2).

Figure 2.6: Tapio's elasticity of decoupling



(Author's compilation; Source: Tapio (2005)

The interpretation of each decoupling elasticity state is briefly mentioned as follows:

- *Strong decoupling*: In this stage of decoupling, carbon emission levels decrease while industrial growth is positive from the preceding year. Therefore, it is considered the ideal state for any industry.
- *Weak decoupling*: This state of decoupling elasticity occurs when carbon emission rises but at a lower rate than industrial growth from last year.
- *Weak negative decoupling*: Here, carbon emission levels fall down but at a lower proportion than the negative industrial growth rate from the preceding year.

- *Expansive coupling*: It takes place when the growth rate of both carbon emissions and industrial growth is approximately equal from the past year.
- *Recessive coupling*: Here again, carbon emission levels and industrial growth depict approximately equal negative changes from the preceding year.
- *Expansive negative decoupling*: It occurs when the rate of increasing carbon emissions is higher than the attained industrial growth from last year.
- *Recessive decoupling*: In this state, carbon emissions decrease at a lower rate than the negative industrial growth changes from the past year.
- *Strong negative decoupling*: It is applicable when carbon emissions continue to rise even when industrial growth reflects negative growth from the preceding year. It is the most harmful decoupling state from the environmental perspective.

2.3.2. Review of empirical studies:

In recent times, studies have used the decoupling index mostly to investigate the responsiveness of the environment towards one's economic growth. Liu et al. (2016) conducted an empirical decoupling study in which they considered three elasticity categories: absolute decoupling, relative decoupling and degenerative decoupling. The study focused on the GDP elasticity of nonferrous metal consumption in China from 1995 to 2010. Zhou et al. (2017) used the OECD decoupling index approach to analyze the responsiveness of carbon emissions towards the economic growth in China's power industry. Peng et al. (2020) also used the OECD framework to find the decoupling relationship between China's electricity production rate and CO_2 emissions. However, Tapio's eight-elasticity decoupling approach has been more widely employed in empirical studies. Chen et al. (2022) implemented this approach to find the elasticity of economic growth in Zhejiang Province in China of their CO_2 emission levels from 2007 to 2019. The study reported a weak decoupling relationship between the observed indicators for the province. However, the province's cities demonstrated mixed results in the decoupling stages. Yuan et al. (2022) applied Tapio's decoupling approach to study the responsiveness degree of carbon emissions toward China's financial development. The results showed weak decoupling and strong negative decoupling in most of the years from 2000 to 2019. Moreover, studies have implemented Tapio's decoupling index to assess various industries' environmental pressure. For example, China's manufacturing industry (Hang et al., 2019; Lv et al., 2021; Ren et al., 2014); China's transportation, manufacturing, retail and accommodation, agriculture and construction industries (Dong et al., 2020); China's iron and steel industry (X. Wang et al., 2020); China's equipment manufacturing industry (Wan et al., 2016), Iran's agricultural sector (Naghavi et al., 2022), etc.

In the existing literature, the application of the decoupling index for assessing industrial sustainability has been very limited, especially in the Indian context. Moreover, no studies have been found to address this issue for the Indian core industries. The present study aims to fill this gap through an investigation of the Indian core industries' environmental efficiency levels using Tapio's decoupling approach, adding more substance to the study's empirical outcomes.

2.4. Determinants of carbon emissions:

2.4.1. Theoretical background:

Economic growth and carbon emissions: The environmental Kuznets curve (EKC) hypothesis is one of the most popular approaches for determining the relationship between economic growth and environmental degradation (Grossman and Krueger, 1991, 1995; Kuznets, 1955). This hypothesis portrays an inverted U-shaped curve relationship between economic growth and environmental deterioration. As an economy grows, initially it imposes ecological destruction due to technological setbacks, dependence on fossil fuel energy sources, less awareness, etc. However, the economy overcomes these obstructions gradually when a considerable growth level is realized. Therefore, after a specific point of growth, economic growth enhances its environmental competence, reduces stress on the environment and improves the overall quality of the environment in the long run.

Economic growth primarily depends upon industrial and agricultural development. In the initial stages of growth in a country, the Scale Effect subdues the Technical Effect of industrial production if industrialization takes place without considering appropriate measures for safeguarding the environment, (Htike et al., 2022). The Scale Effect refers to the increasing production levels whereas the Technical Effect depicts the role of technological upgradations in enhancing sustainable industrialization (Adeel-Farooq et al., 2021). In such a situation, economic growth achieved through industrialization is expected to cause detrimental ecological consequences. The same is true for agricultural expansion. This is in line with the first phase of the EKC hypothesis.

Technological advancement and carbon emissions: The endogenous growth model propounded by Romer (1986), argues that technological innovation and knowledge attainment play critical roles in achieving long-term and stable economic growth (Adenutsi, 2011; Lucas, 1988). The theory emphasizes the need for significant investment in research and development activities and devotes considerable attention to building quality human capital in order to achieve faster economic growth. Investment in research and development brings technological innovation and knowledge capital to the industrial and agricultural sectors, which helps to achieve sustainable growth without compromising the environment. Thus, the Technical Effect dominates the Scale Effect of production and enables the second stage of the EKC hypothesis, where economic growth achieves environmental harmony.

Energy consumption and carbon emissions: Modern literature has also hinted at the U-shaped renewable energy EKC (REKC) hypothesis (Nabaweesi et al., 2024; Yao et al., 2019). According to the hypothesis, in the initial growth stages, the economy and renewable energy share an inverse relationship which is not desirable for the environment. The cost of renewable energy is generally high in developing countries due to which high reliance on conventional, cheaper and high-polluting fossil fuel energy is observed. After attaining a certain threshold, greater generation and consumption of renewable energy helps an economy improve its environmental quality.

Foreign direct investments (FDI) and carbon emissions: The impact of FDI on the environment can be explained by the pollution haven and pollution halo hypotheses. The former explains that developed countries often transfer their high-polluting industrial operations to developing nations, causing environmental degradation in the host countries (Mani and Wheeler, 1998; Martínez-Zarzoso et al., 2016). In contrast, the pollution halo hypothesis documents the benefits that a host country may receive from quality FDI opportunities (Demena and Afesorgbor, 2020; Q. Liu et al., 2018). The hypothesis argues that FDI promotes the sharing of technological knowledge and skills between developed and developing countries, leading to favourable environmental outcomes for the developing host nations.

Financial development and carbon emissions: The linkage between financial development and environmental degradation has been described by the capitalization effect, technology effect, income effect and regulation effect. The capitalization effect holds that financial development helps the growth of small-scale industries that add to environmental pollution due to their lack of economies of scale and pollution-controlling means (Hunjra et al., 2020). 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). The income effect suggests that financial development can bring about long-term economic growth which may have either a positive or negative environmental impact depending on the quality of growth (Idrees and Majeed, 2022; Yuxiang and Chen, 2011). The regulation effect argues that financial development encourages favourable ecological outcomes when effective environmental regulations are executed (Li et al., 2020).

Population growth and carbon emissions: The IPAT model helps analyse the relationship between population size and environmental degradation (Danish et al., 2021; Ehrlich and Holdren, 1971; Preston, 1996). As per the equation, environmental impact (I) is a product of population (P), affluence (A) and technology (T). The model asserts that if the population grows, it increases environmental stress through greater demands for limited resources in the economy. As a result, the environmental balance of the economy is compromised.

Urbanization and carbon emissions: The relationship between urbanization and environmental degradation can be explained with reference to the ecological modernization theory (Ansari et al., 2020; Sadorsky, 2014). The theory suggests that when societies shift from low to middle development stages, environmental degradation is often guaranteed. In this stage, the focus of the urban locations on economic growth overtakes the environmental concerns. When societies move towards a high development stage, it is capable of bringing environmental balance between urbanization and environmental welfare. The urban environmental transition theory also posits that both positive and adverse environmental impact can be expected from urbanization (McGranahan et al., 2001; Sadorsky, 2014). Usually, urban locations become wealthier due to the industrial setups. While on one hand, more industrial operations lead to higher pollution levels through greater energy consumption, on the other, more wealth generation enables industries to focus more on innovation and technological upgrades to reduce ecological destruction. In that case, the net environmental effect of urbanization is difficult to determine. It majorly depends on the urban policies in practice.

2.4.2. Review of empirical studies:

Table 2.2 provides an overview of empirical studies exploring the various determinants of environmental degradation. These studies have considered CO_2 emission as an indicator of environmental degradation. The last column of the table mentions the direction of the effect of the various drivers on carbon emissions.

Table 2.2: Reviewed articles on drivers of environmental degradation

Authors (Year)	Focused country(s)	Identified driver(s)	Direction of effect
Jalil and Feridun (2011)	China	Energy use	Positive
		Economic growth	Positive
		Financial development	Negative
		Trade openness	Positive
Sehrawat *et al.* (2015)	India	Financial development	Positive
		Energy consumption	Positive
		Economic growth	Positive
		Trade openness	Non-significant
		Urbanization	Positive
Lin *et al.* (2015)	Nigeria	Population	Positive
		Economic growth	Positive
		Energy intensity	Positive
		Carbon intensity	Positive
		Industrialization	Negative
Boamah *et al.* (2017)	China	Economic growth	Negative
		Energy consumption	Positive
		Exports	Non-significant
		Imports	Positive
		Urbanization	Non-significant
Asumadu-Sarkodie and Owusu (2017a)	Senegal	Financial development	Positive
		Electricity consumption	Positive
		Industrialization	Positive
		Urbanization	Negative
		Economic growth	Negative
Asumadu-Sarkodie and Owusu (2017b)	Rwanda	Economic growth	Negative
		Industrialization	Positive
		Population	Non-significant
Xu *et al.* (2018)	Saudi Arabia	Electricity consumption	Positive
		Financial development	Positive
		Economic growth	Positive
		Urbanization	Negative
		Globalization	Non-significant
Yu and Xu (2019)	China	FDI	Negative
		Industrial structure	Positive
		Economic growth	Positive
		R&D	Positive
		Urbanization	Positive
		International trade	Negative
		Emission intensity	Positive

		Population	Positive
		Energy structure	Positive
Udemba (2020)	India	Economic growth	Positive
		Agriculture	Positive
		FDI	Non-significant
		Energy use	Positive
		Urban population	Positive
Nathaniel (2020)	Multiple	Energy use	Positive
		Urbanization	Non-significant
		Economic growth	Positive
		FDI	Positive
Shahbaz *et al.* (2020)	United Arab Emirates	Financial development	Positive
		Energy consumption	Negative
		Economic growth	Positive
		Economic globalization	Negative
Zafar *et al.* (2020)	Multiple	Industrialization	Positive
		Economic growth	Negative
		Energy consumption	Positive
		Urbanization	Positive
Yuping *et al.* (2021)	Argentina	Economic growth	Positive
		Non-renewable energy	Positive
		Renewable energy	Negative
		Economic globalization	Negative
Elfaki *et al.* (2022)	Multiple	Economic growth	Negative
		Energy consumption	Positive
		Financial development	Positive
		Industrialization	Negative
Ali and Yi (2022)	Pakistan	Urbanization	Positive
		Energy use	Positive
		Economic growth	Non-significant

(Authors' compilation)

In Table 2.2, it is observed that an increasing number of studies have been conducted in this area, particularly since 2020. However, these studies have mostly addressed the issue of an economy and fail to highlight the problem at the industrial level. Besides, no studies have explored the drivers of emissions in the Indian core industries. The present study aims to address this gap by emphasizing the drivers of environmental degradation for the Indian core industries. Additionally, the study considers other important factors such as industrial design, banks' credit support, education, poverty, etc. that could also be potential determinants of carbon emission.

2.5. Chapter summary:

The present chapter provided a detailed overview of the available literature on the environmental dynamics of industrialization and the related theoretical background. The review of the empirical studies helps understand the research gaps in this research area. The study tries to make a novel contribution to the existing literature by addressing the research gaps.