Sustainable Entrepreneurship and Renewable Energy Innovation in India: Evidence from Energy Emissions Nexus Studies

Simran Sehgal*

**Research Scholar, Department of Economics, SOSS, IGNOU*
Email: simransehgal1203@gmail.com

Abstract
This study examines the methodological evolution in the empirical literature analyzing the association between carbon emissions, economic growth, and energy consumption in India. Understanding this relationship is critical for designing strategies that support sustainable economic development while addressing environmental challenges associated with increasing energy demand. The study aims to evaluate how different econometric methodologies influence the interpretation of the energy emissions nexus and to highlight their implications for sustainability, renewable energy innovation, and sustainable entrepreneurship in emerging Asian economies. A systematic methodological review approach was adopted to analyze empirical studies published between 2015 and 2025. Relevant articles were identified through major academic databases and screened using predefined inclusion criteria focusing on studies that employ advanced econometric models such as Autoregressive Distributed Lag (ARDL), Vector Error Correction Model (VECM), and Nonlinear Autoregressive Distributed Lag (NARDL). The findings reveal a clear transition in the literature from traditional linear models toward nonlinear and asymmetric econometric frameworks. While linear models provide useful insights into long-run equilibrium relationships, asymmetric models offer a deeper understanding of structural dynamics by capturing differential responses to positive and negative economic shocks. The results also highlight the growing importance of technological innovation, renewable energy adoption, green enterprises, and sustainable entrepreneurship in reducing environmental degradation. By integrating insights from environmental economics, sustainability research, and entrepreneurial innovation, the study contributes to a better understanding of how methodological advancements can inform policy and enterprise development aimed at supporting energy transition and sustainable development in emerging economies.

Keywords: sustainable entrepreneurship; renewable energy innovation; green enterprises; energy transition; energy–emissions nexus; environmental sustainability; ARDL; NARDL

1. INTRODUCTION

The growing concern about environmental deterioration and climate change has escalated academic inclination to analyse the connexion between carbon emissions, energy consumption, and economic growth. With the growth of world economies, energy demand keeps growing, and this causes the strain in natural resources and the increase of greenhouse gases emissions. The problem is especially important in fast-growing economies where industrialization, urbanisation, and resource creation of infrastructure is based on the production system that is energy-consuming. The nature of the intricate relationships between energy consumption, economic growth, and environmental sustainability has consequently emerged as a relevant field of research in environmental economics and sustainability research (Acheampong, 2018; Ito, 2017; Saidi and Hammami, 2015; Leitão, 2014). In more recent years, sustainable entrepreneurship has also become an area of increasingly intersecting discussion in entrepreneurship research, as novel entrepreneurial initiatives and sustainable enterprises are understood to play a significant role in the creation of technologically- and organizationally-based solutions to environmental issues.

India is one of the contexts in which such dynamics are the most applicable as it is rapidly growing economically, and energy consumption is growing. India is one of the largest emerging economies in Asia and over the past few decades, there have been significant growth in the production levels of industry, transportation activities and urbanisation in India. The changes have been associated with an increase in energy consumption and carbon emission, and therefore, environmental sustainability is one of the primary policy challenges. Although economic growth has enhanced living standards and generated more economic opportunities, it has also enhanced environmental pressures. Therefore, it has become the central topic of policymakers and researchers to find approaches in order to ensure that economic development may be achieved without causing environmental degradation (Acheampong, 2018; Balsalobre-Lorente et al., 2018; Karedla et al., 2021). In this backdrop, entrepreneurship and innovation-based enterprises are gaining prominence in facilitating sustainable development trajectories through the

introduction of new technologies, sustainable business models, and production systems that are environmental friendly.

The energy consumption-environmental outcome relationship is commonly modelled as energy-growth-emissions nexus, which studies the impact of economic activity on the environmental measure of such indicators as carbon dioxide emissions. The growth of any economy in most developing economies is directly associated with the use of fossil fuels especially coal and oil. The energy sources continue to dominate because of the availability and their relative cheapness but they are a major contributor to the pollution of the environment and climatic change. Consequently, the emerging economies have to grapple with the problem of adopting cleaner and more sustainable energy infrastructure without necessarily reducing the pace of economic development (Awodumi & Adewuyi, 2020; Ito, 2017; Shahani and Bansal, 2020). To solve this issue, technological advances and the introduction of new policies are not sufficient but innovative entrepreneurial projects that can change the energy systems and contribute to the sustainable industrial growth as well.

The process of moving to renewable energy has received growing momentum in recent years as one of the major solutions to environmental sustainability. Renewable energy sources like solar, wind and hydroelectric power present a promise of minimising carbon emissions but also aid in the development of the economy in the long run. Along with the technological aspect, the entrepreneurial innovation is relevant in the acceleration of the introduction of the sustainable energy systems. Sustainable entrepreneurship is the process by which innovative entrepreneurship and companies come up with solutions that will solve the environmental and the social problems as well as generate economic values. Regarding the energy transitions, green technology startups and renewable energy businesses are oriented at the creation of cleaner energy infrastructure, energy-efficient production, and sustainable business models that facilitate the environmentally responsible economic growth (Apergis and Payne, 2015; Balsalobre-Lorente and others, 2018; Sreenivasan and Suresh, 2024). These entrepreneurial programmes are very important in supporting green innovation, adoption of renewable energy, and development of new markets in the sustainable energy sectors in most of the emerging economies.

In the last 20 years, empirical studies of the energy nexus of emissions have increased significantly. In the study of the connexion between economic growth, energy consumption, and environmental degradation, scholars have used numerous methods of econometrics. Most of the traditional researches have used linear econometric models like the ARDL and the VECM model to approximate the long-run relationship between macroeconomic variables. The models expect a proportional change in the explanatory variables to cause a proportional change in environmental indicators, which is a simplified depiction of economic and environmental interactions (Acheampong, 2018; Ito, 2017; Karedla et al., 2021). Although such models have offered good insights into the macroeconomic dynamics of environmental change, they might not be able to reflect the complicated dynamics of technological innovation, structural change, and entrepreneurship undertaken within the contemporary energy systems.

According to the recent studies, it is not necessarily the case that environmental dynamics are symmetric. The economic variables have a tendency to react differently to economic positive and negative shocks, especially in the areas where a technological innovation and structural change are involved (Acheampong, 2018). With this realisation in mind, researchers have over time turned to non-linear econometric models especially using the NARDL model. Such models enable the researcher to reproduce asymmetric responses to environmental indicators, which can be used to gain a more detailed insight into the relationship between economic growth and environmental sustainability (Awodumi and Adewuyi, 2020; Balsalobre-Lorente et al., 2018; Khan et al., 2026). These analytical advances are especially pertinent when it comes to green industries and markets in renewable energy where the entrepreneurial innovation and the technological change could affect the environmental performance in complex and dynamic ways.

The existence of the energy emissions nexus literature is still receiving an increased amount of literature, but, even so, there is a necessity of systematic review on methodological approaches in the research area. Numerous studies are largely concerned with the empirical findings and do not critically review how the various econometric models have an implication on the interpretation of the environmental dynamics. The methodological decisions may have a huge impact on the research output and policy suggestions, especially when it comes to sustainability and the energy transition. These differences in methodologies are therefore critical in coming up with more precise analytical frameworks of sustainability research and finding policy measures that can help promote innovativeness and sustainable growth of enterprises.

The current study offers a methodological review of the systematic approach to the econometric methods of examining the energy emissions nexus in India. The comparison of linear and non-linear modelling frameworks is aimed at determining patterns in methodology in literature and assessing the impact that various ways of analysis have on empirical

results. Besides, the research also indicates the implication of these methodological developments on sustainable entrepreneurship, green innovation, and development of renewable energy enterprises in new emerging energy markets. This analysis helps the study to better understand the methodological development in the research on environmental economics and also offers some information on how a fast developing economy can also achieve a transition to sustainability with the help of entrepreneurial innovation.

2. THEORETICAL BACKGROUND

2.1 Energy Growth Emissions Nexus

The connection between the consumption of energy and economic growth and, in turn, environmental degradation has become one of the key topics of environmental economics and the study of sustainability. The high rate of industrialization, urbanisation and technological development has also led to increased energy demand in the world given that energy is a vital element in fueling economic growth; it is also a key factor that has been linked to the emission of greenhouse gases and environmental destruction (Mardani et al., 2019; Rahman and Vu, 2020). This relationship is thus critical in coming up with policies that will ensure economic growth and environmental sustainability.

In most developing economies like India, economic growth has been historically coupled with the rise in the use of fossil energy especially coal and oil. The same sources have been used to power industrial production and the development of infrastructure, but they have also increased carbon emissions (Rahman and Vu, 2020; Ulucak and Khan, 2020). This has consequently drawn more and more researchers who have sought to study the dynamic interactions between economic growth, energy consumption, and environmental sustainability. It is often called the energy -growth-emissions nexus which offers a conceptual framework in which the impacts of economic activity on the environment are viewed.

Considered through the prism of sustainability, the nexus of energy growth also brings forth the significance of switching to more environmentally friendly sources of energy and enhancing the efficiency of energy consumption. The use of renewable energy technologies, technological innovation, and sustainable business practises is also becoming an important contributor to environmental sustainability (Ben Jebli & Ben Youssef, 2017; Ulucak and Khan, 2020). In that regard, the role of entrepreneurial innovation in renewable energy systems and green technologies is significant in ensuring that a switch is made to sustainable energy systems. Sustainable entrepreneurs help in solving the environmental issues that are related with economic development by coming up with new technologies and new business models that minimise environmental effects.

2.2 Environmental Kuznets Curve (EKC) Hypothesis

The EKC hypothesis is one of the most common theoretical approaches that are applied to explain the interaction between economic growth and environmental degradation. The EKC hypothesises an inverse U-shaped relationship between the level of incomes and environmental degradation. This theory postulates that in the early phases of economic growth, the rate of environmental degradation is high because the size of the industrial sector is growing as well as the volume of energy consumed (Leitão, 2014; Sebri & Ben-Salha, 2014). But after reaching a threshold, the environmental quality starts rising and the economies start to use cleaner technologies, introduce environmental regulations, and change towards less pollutant-intensive businesses.

EKC framework has been extensively used to conduct empirical studies on the nexus of energy and emissions in developed and developing economies. During the initial phase of industrialization, the economy is usually very dependent on the use of fossil fuel and production processes that absorb a lot of energy leading to the emission of carbon (Rahman and Vu, 2020). With the increasing trend of the more technologically and eco-conscious economies, investments in green energy, environmental control, and sustainable infrastructure start to cut emissions. Empirical data on the EKC hypothesis is still inconclusive in terms of India. There is some research to confirm the presence of an inverted U-shaped relationship between economic growth and environmental degradation; other studies do not provide evidence of a definite turning point in the trends in emissions. These contradictory results indicate that the environmental performance is determined by an array of variables and some of the most important factors include technological innovativeness, institutional standards, and energy policy structures (Mardani et al., 2019). Using the EKC framework, sustainable entrepreneurship emphasises innovation-based solutions to facilitate more sustainable production systems and business models that are environmentally friendly.

2.3 Linear Econometric Frameworks in Environmental Analysis

Conventional empirical research on the nexus of energy emission has been based to a great extent on econometric models that are linear in nature to provide an estimate of the relationship between economic growth and energy consumption on the other hand and environmental indicators. Linear models are based on the assumption that the alteration of factors of explanation results in proportional change in environmental results. That

is, any gains and losses on economic variables are supposed to cause balanced reactions on environmental indicators.

The ARDL model is one of the most popular linear econometric models that enable a researcher to test both short-term and long-term relationships among variables. ARDL model has a lot of application in situations where the time-series data involve variables which are integrated at various orders like I(0) and I(1). This has made ARDL appeal to many when examining the environment sustainability in developing economies where data constraints might prevail (Mardani et al., 2019).

One more type of linear framework is the VECM that is utilised in the study of causal relationships between variables that are cointegrated in the long run (Pachiyappan et al., 2021). The VECM method enables the researcher to investigate the adjustment of deviations of long-run equilibrium relationship over time. Though these models can offer valuable information on macroeconomic relationships, they assume symmetric adjustments, which in might not adequately reflect structural changes that transpire within an energy system.

2.4 Non-Linear and Asymmetric Modeling Approaches

In response to the shortcomings of the symmetric econometric modelling, more recent studies have increasingly reconciled to non-linear modelling techniques to study the dynamics of the environment. With non-linear model, a researcher is able to model asymmetric responses in economic and environmental variables, that is positive and negative shocks can result in different outcomes. This point of view is especially applicable to the situation when the system of energy is being structurally changed by technological innovation and policy interventions (Ulucak & Khan, 2020).

NARDL is among the most common asymmetric econometric models which have gained popularity in the field of environmental economics research. The NARDL methodology is an extension of the conventional ARDL model as it breaks down the explanatory variables into negative and positive partial sums (Khan et al., 2023). The decomposition allows the researcher to analyse the value of gains and losses of economic variables to produce varied results on the environment.

The introduction of asymmetric modelling paradigms indicates the increasing awareness that environmental processes are affected by intricate structural variables including technological innovations, policy interventions and changes in behaviour in energy use. To illustrate, an investment in renewable energy technologies can potentially cut down on emissions in the long run, whereas economic shocks can have different effects on environmental outcomes (Rahman and Vu, 2020). Non-linear models are able to capture such asymmetric dynamics as a more realistic representation of the energy emissions nexus.

2.5 Sustainable Entrepreneurship and Energy Transition

The shift to the sustainable energy systems has generated new entrepreneurial opportunities and sustainable enterprise development opportunities. Sustainable entrepreneurship is a process by which the opportunity identified and exploited by entrepreneurs responds to environmental and social issues, as well as, creation of economic value (Ben Jebli & Ben Youssef, 2017).

Within the framework of energy transitions, the key role is taken by sustainable entrepreneurs who tend to create renewable energy technologies, energy-efficient production systems, and environmentally friendly business models.

The startups of green technology, renewable energy, and sustainable infrastructure development are major parts of emerging entrepreneurial ecosystems that are directed towards environmental sustainability. Such projects help in curbing carbon emission and at the same time enhance economic growth and advancements in technology (Ulucak & Khan, 2020). Entrepreneurial innovation is especially relevant in emerging economies like India, where it is necessary to hasten the implementation of renewable energy technologies and ensure sustainable industrial operations.

The interplay of technological innovation, entrepreneurs, and environmental sustainability explains why interdisciplinary methods of research are important in sustainability studies. The combination of information on environmental economics, entrepreneurship research, and technological innovation could help researchers to gain a better insight into the processes whereby sustainable entrepreneurship will help in dealing with global environmental issues (Mardani et al., 2019). As a result, the discussion of the methodological ways of analysing the energy-emissions nexus would be useful in terms of the alignment of the strategies of economic development with the goals of sustainability and entrepreneurial innovation. Entrepreneurial innovation has been identified as a key mechanism that is essential in hastening the shift to sustainable energy systems. Entrepreneurs and small businesses in the emerging economies are significant in the creation of renewable energy technology, energy efficient solutions, environmentally friendly production procedures. These entrepreneurial actions help in commercialization of the clean technologies and the development of the sustainable business models that can facilitate the economic growth of the low-carbon economies. There has also been an opening of new opportunities by the green business and innovation-based startups associated with the growth of renewable energy markets, which include the areas

of solar energy, clean technology services, and decentralised energy systems. Entrepreneur ecosystems have the potential to have a huge impact on how fast and efficient the energy transition in booming economies becomes when they are used to promote both technological innovation and sustainable enterprise growth. The conceptual framework of the study is shown in the Fig. 1. It describes how policy-based support and the institutional environment in general help to enhance entrepreneurial ecosystems by enhancing access to capital, incubators and innovation networks.

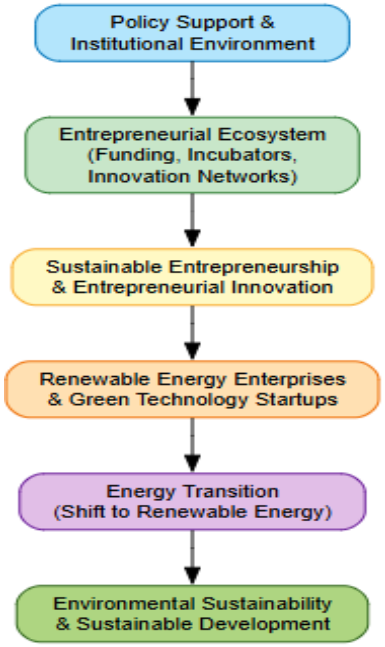

Figure 1. Conceptual framework linking policy support, entrepreneurial ecosystems, sustainable entrepreneurship, renewable energy enterprises, energy transition, and environmental sustainability

3. METHODOLOGY

3.1 Research Design

This research paper utilises a systematic methodological review process to explore the development of econometric tools that can be used to analyse the relationship between energy consumption, economic growth, and carbon emissions in India. The aim of this strategy is not merely to describe the empirical results but to strictly analyse the effect of various econometric specifications on the explanation of environmental dynamics, as well as sustainability outcomes. These differences in methodology are of special interest when it comes to the emerging economies where energy transitions and environmental policies interact with economic development in a way that is difficult to understand. Through comparison of the methodological underpinnings of the current empirical research efforts, the study will be able to determine trends in model selection and the impacts of these selections on inferences about the energy-emissions nexus.

The methodological scheme is based on a systematic analytical process that enables the systematic identification, organisation, and comparison of empirical studies. This is done by following multiple steps such as identification of literature, screening and eligibility, data extraction and organisation, methodological classification, and comparative evaluation. Such designed form is transparent and reproducible, and allows to cover the entire examination of the econometric methods employed in the literature. In this process, the study gives a critical evaluation of how the methodological developments have contributed to the comprehension of sustainability issues and dynamics of environmental policies in India.

Besides assessing the newest developments in the field of methodology in environmental economics, the current review also addresses the wider consequences of these methodologies to sustainable entrepreneurship and green innovation. The knowledge of methodological principles of energy-emissions nexus studies would be a valuable component of the comprehension of the impact of technological change, the introduction of renewable energy and enterprises led by innovations on the ecological sustainability. In the developing economies like India, the role of entrepreneurial venture and renewable energy ventures is on the development of sustainable technologies and environmental friendly business models. Thus, the analysis of the methodology development of empirical research can not only enhance analytical knowledge of the environmental processes but also serve to recognise the possibilities of innovation, sustainable development of the enterprise, and

entrepreneurial activities in changing energy markets.

3.2 Data Collection and Literature Identification

This study relied on the dataset that was gathered through comprehensive research in big academic databases, such as Scopus, Web of Science, and Google Scholar. The search strategy targeted peer-reviewed journal articles published between 2015 and 2025, which is a time period indicating that there have been major transformations in the Indian energy sector after the country ratified the international climate agreements and the rapid growth in renewable energy capacity. By choosing this period, it is possible to encompass the current research which reflects the dynamic aspects of the energy consumption, economic development and environmental sustenance.

The search strategy was the systematic key word searching to find the relevant studies. To find articles assessing the energy-emissions relationship using sophisticated econometric methods, the Boolean search expressions were made of the keywords: India, CO_2 emissions, energy consumption, ARDL, NARDL, asymmetric modelling, and cointegration. All the search results of the various databases were also merged to form one dataset to make systematic screening easier. This was followed by the removal of duplicate entries which was done by automated comparison of article titles, authors and publication details. This process of consolidation was what guaranteed that only unique and relevant studies were contained in the dataset to be further evaluated.

3.3 Screening and Eligibility Assessment

After a primary literature search, a systematic screening procedure was carried out to identify only the useful and methodologically rigorous studies to include in the analysis. The screening process was done on a step wise basis where the dataset was narrowed down on a narrow-cut set of eligibility rules. To select the articles that concerned the relationship between energy consumption and economic growth and the environmental indicators like the quantity of carbon emissions or ecological footprint, in the first stage, the titles and abstracts of the retrieved articles were examined.

A number of inclusion criteria were used to ensure that the process of analysis was consistent. The studies identified needed to specifically target India either a one country study or a panel study in which the results were presented as country-specific. Besides that, the research had to use high level econometric methods which would analyse the long-term relationships between macroeconomic and environmental variables. Particularly, the papers based on such an econometric model as the ARDLmodel, VECM, NARDL model, or other asymmetric cointegration approaches, were deemed eligible to be included. In addition, peer-reviewed journal articles were only kept so that the quality and reliability of the findings were guaranteed.

The nullification of studies was done by the exclusion of studies which were based on descriptive statistics, simple regression analysis or theoretical discussions without the modelling of the studies. Publishes that were not detailed enough on their methodology or covered different areas of India were also eliminated. Having used these screening criteria, the manufacturers of over one hundred articles narrowed down to a final sample of twenty empirical studies, which could be compared with each other in a systematic manner.

3.4 Data Extraction and Structuring

After identifying the final set of studies, appropriate methodological and empirical data concerning each were obtained and tabulated into a structured analytical data set. The aim of this step was to develop a set of standard framework through which a useful comparison of various empirical studies would be possible. The main characteristics of each article were listed such as authors and the year of publication, the time span encompassed by the information, the econometric tools used, the major variables that were used in the model, the main empirical results of the article and methodological constraints the authors have stated.

The information extracted was synthesised into a synthesis matrix which was the major tool of analysis of the review. This matrix facilitated the systematisation of studies with the approach used in their econometrics and their studies. A tabular formulation of the data helped the synthesis matrix to detect methodological trends within the literature, especially the shift towards more sophisticated asymmetric models on the basis of the traditional symmetric econometric models. The structured organisation also enabled the study to contrast the results of the empiricism study in various methodological approaches without losing any consistency in the analytic process. This synthesis of the reviewed research has resulted in a synthesis table summarising the reviewed studies as shown in Table 1.

Table 1: Summary of Selected Empirical Studies on India's Energy–Emission Nexus (2015–2025)

Author(s) & Year	Data Period	Methodology	Key Variables	Key Finding
Ohlan (2015)	1970–2013	ARDL	CO_2, Population, Energy, Trade, GDP	Population density drives emissions

Sinha & Shahbaz (2018)	1971–2015	ARDL	CO_2, Renewable Energy, Fossil Energy	Renewable energy reduces emissions
Akalpler & Hove (2019)	1971–2014	ARDL	CO_2, Energy, GDP, Trade	Energy and GDP increase emissions
Sahu & Kumar (2020)	1971–2014	ARDL	CO_2, Globalization, Finance	Globalization reduces emissions
Pachiyappan et al. (2021)	1980–2018	ARDL & VECM	CO_2, Energy, GDP	Energy consumption causes emissions
Ahmad et al. (2018)	1980–2014	NARDL	CO_2, GDP, Energy	Asymmetric relationship identified
Neog & Yadava (2020)	1980–2014	NARDL	CO_2, Remittances, Finance	Positive shocks increase emissions

3.5 Methodological Classification

Following the data obtained in the chosen studies, two main methodological categories of literature were determined based on the frameworks applied in the econometrics of analysis. The former category includes the works that utilise linear econometric models, especially, the ARDLmodel and VECM. The assumptions of these models imply that there will be a symmetric association existing between the explanatory variables and environmental outcomes; in other words, an increase and/or a decrease in an explanatory variable like the consumption of energy or economic growth is predicted to have a corresponding impact on the carbon emissions.

Linear econometric models have found considerable application in environmental economics because they allow the accommodation of variables of varying degrees of integration, and because they are appropriate to comparatively small time-series data. They are especially effective because of these characteristics in the analysis of macroeconomic relationships in developing economies where long-term databases might be scarce. But symmetry that is implicit in these models can be misleading in models that are highly complex in nature such as the contemporary energy systems.

Studies that use non-linear econometric models especially the NARDL model and analogous asymmetric modelling methods) fall into the second category. The models build on the ARDL models by disaggregating the explanatory variables into both positive and negative partial sums to enable the researcher to test whether increases and decreases in economic variables result in varied responses to the environment. It is a method that can find special use when structural inflexibility and asymmetric adjustments in changing systems of energy are to be captured. Non-linear models can give a more subtle account of the energyemissions nexus by making a distinction between a positive and negative economic shock.

3.6 Comparative Analytical Framework

The last step of the methodology is comparative assessment of the two streams of methodology in order to determine their relative strengths, limitations as well as implications on policy. Some of the major dimensions that the comparative analysis aims at include statistical robustness, flexibility of the model and policy relevance. Statistical robustness is a concept of the capacity of any econometric structure to generate stable and reliable estimations in various data situations. The flexibility of the models relates to the ability of each strategy to understand the structural changes and asymmetric dynamics in energy systems. The policy relevance analyses the effect of the methodology of econometrics selected on the interpretation of the empirical results and the development of sustainability policies.

The paper under this comparative framework compares the differences between linear and non-linear econometric models on their capability to reflect the complex interaction between energy consumption, economic growth and environmental outcomes. Although the linear models are simple to estimate and interpret the relationship between the variables of long run equilibrium, non-linear models have more flexibility when it comes to asymmetric adjustment and structural changes within the economy. The research by looking at these methodological variations informs on the changing tools of analysis of sustainability research and the increasing significance of asymmetric econometric models in the study of environmental transitions.

3.7 Reproducibility and Analytical Transparency

To have a transparent analytical and reproducible method, the entire review procedure, including literary search to methodological categorization, was carried out using a detailed computational workflow that limited manual biasness. The data processing functions like duplicate removal, filtering and tabulation were done in a systematic manner that was congruent throughout the dataset. The systematic analysis process also helps in duplicating the research by other researchers who might like to have another analysis of the research to other countries or periods of time.

The study is also useful in contributing to the existing body of literature on systematic review research on environmental economics and sustainability. This

would help make sure that the conclusions made based on the analysis are made on the basis of a full-fledged, systematic organised body of empirical evidence.

4. THEMATIC ANALYSIS

4.1 Linear Econometric Approaches and the Foundations of Sustainable Energy Transition

The initial empirical research studies that investigated the nexus of energy and emission in India have mostly used the linear type of econometric studies. The majority of the studies used symmetric models in 2015-2020 that included the ARDLbounds testing model alongside the VECM. The assumptions of these econometric methods are that when changes in the explanatory variables are positive or negative, they have equal impacts on the environmental indicators. In its practical application, it implies that as there is an increase in the amount of energy consumed, there would be an equivalent increase in the emissions of carbon as there would be a corresponding decrease in the emissions of carbon in the event that the amount of energy consumed is reduced. These kinds of assumptions give a simplistic method of analysing the macroeconomic relationships but can be ineffective in terms of analysing the complex nature of the environmental and economic interactions.

The ARDL model suggested by Pesaran et al. (2001) has gained a lot of popularity because of the ability to work with variables incorporated at various levels, especially I(0) and I(1). This is due to the fact that ARDL is flexible enough to fit macroeconomic time-series data that are usually considered when examining developing economies. This model has been used empirically in the Indian context and the constant trend is that a high connexion exists between energy consumption and environmental degradation. Other researchers, including Ohlan (2015) and Shahani and Bansal (2020), found a positive correlation between energy consumption and carbon emissions, which suggests that the rapid development of the economy based on the use of fossil fuels as the main source of energy can worsen the load on nature.

Other works generalised the ARDL framework by adding more explanatory variables, which reflect more economic and structural dynamics. To illustrate, Sinha and Shahbaz (2018) also considered the concept of renewable energy consumption in their study and empirically have supported the Environmental Kuznets Curve (EKC) hypothesis. Their results indicate that economic growth and growth of renewable energy can ultimately result in emission reduction. On the same note, Karedla et al. (2021) focused on industrial activity by showing that growth in the manufacturing sector is a major cause of environmental degradation.

These findings have implications on sustainable entrepreneurship as new ideas have to be developed that will decrease the use of fossil fuels and ensure cleaner production systems. The close connexion between economic activity and environmental degradation implies that the key to environmental sustainability in the long-term is the emergence of renewable energy technologies, energy-efficient production processes, and sustainable industrial operations by the entrepreneurship. The growth of green business and clean technology startups in developing economies like India is vital in the process of making the shift to the low-carbon economic systems.

Although these models are analytic, there are limitations to the use of a linear econometric model. The main drawback is that they assume symmetric responses and this could be too simplistic when studying the complex system of an energy system experiencing structural transformation. There is a tendency of path dependency and technological inertia in economic and environmental processes such that growth and decline in economic variables may do not produce similar environmental reactions. Consequently, symmetric models might not reflect the dynamic changes of technological innovation, adoption of renewable energy and entrepreneurship in new energy markets.

4.2 Non-Linear Econometric Approaches and Innovation in Sustainable Energy Systems

To address the shortcomings of symmetric econometric models, more recent studies have been moving towards non-linear and asymmetric modelling methods in the study of the energy-emissions nexus. These strategies acknowledge that economic variables do not necessarily affect the environment proportionately. In lieu of that, positive and negative shocks can produce dissimilar environmental responses under various structural conditions in the economy. This kind of asymmetric action is especially applicable in an industry that is being transformed in terms of technology as it happens in the energy systems shifted to renewable energy sources.

One of the most popular asymmetric econometric frameworks that are currently being applied in environmental economics studies is the NARDL model by Shin et al. (2014). The most important innovation of the NARDL model is that it offers the opportunity to break down the change in the explanatory variables into positive and negative changes. This break down enables the researcher to study the effects of the rise and fall of economic variables on the indicators of the environment like carbon emissions. The NARDL methodology can capture asymmetric adjustments and hence gives more detailed information on the dynamic interaction among economic growth, energy consumption, and environmental sustainability.

The significance of such asymmetric dynamics is noted in empirical evidence of the research studies

conducted on India. As an example, Neog and Yadava (2020) found that there were asymmetric long-run relationships between financial development, remittances, and carbon emissions. They conclude that positive financial shocks have a stronger demand effect on emissions as compared to negative shocks, which depress emissions, which implies that economic growth can aggravate environmental pressure unless it is accompanied by a sustainable technological innovation. In the same way, Mujtaba and Jena (2021) discovered that when prices of oil go up, the result is a decline in emissions because of conservation behaviour, and when the price of oil declines, the corresponding increase of emission is not attained.

The value of technological innovation and energy substitution in influencing the environment has also been shown in other studies. As an illustration, Khan et al. (2026) decomposed fossil fuel use into coal, oil, and natural gas parts and observed that any reduction in coal use generates greater emission reduction than any increase in coal use generates other emissions. These results demonstrate the relevance of technological transition and energy diversification in minimising environmental effects.

These changes are significant to sustainable entrepreneurship. With the move towards renewable energy systems, entrepreneurs and innovative companies have an important role to play in the creation of sustainable technologies, the growth of clean energy systems, and the establishment of business systems that are eco-friendly. Non-linear econometric models are thus helpful to give an idea of the circumstances in which technological innovation and entrepreneurial action can help in the sustainability of the environment.

4.3 Thematic Synthesis of Literature and Implications for Sustainable Entrepreneurship

Thematic synthesis of the conducted review of the literature displays numerous repeated tendencies in the connexion among the themes of energy use, economic development, and environmental sustainability. These themes accentuate the significance of the usage of renewable energy, technological advancement, and economic remodelling of the economic system to diminish environmental degradation. Simultaneously, the literature shows that methodological decisions matter a lot in shaping the understanding of the dynamics of energy-emissions nexus among the researchers.

In order to give a more precise description of thematic patterns observed in the literature, the most important themes that were observed in the reviewed studies are summarised in Table 2. The table shows the prevailing econometric methodologies in each of the thematic categories, the significant empirical results and their implication to sustainability and entrepreneurial innovation.

Table 2. Key Themes in Energy–Emissions Nexus Research and Implications for Sustainable Entrepreneurship

Theme	Dominant Methodology	Key Findings	Implications for Sustainable Entrepreneurship and Green Enterprises
Energy consumption and emissions relationship	ARDL	Energy consumption strongly increases CO_2 emissions	Creates opportunities for entrepreneurs to develop energy-efficient technologies and innovative solutions that reduce environmental impacts
Economic growth and environmental pressure	ARDL / VECM	GDP growth often increases emissions in developing economies	Encourages the emergence of sustainable production systems and green enterprises that promote environmentally responsible economic development
Renewable energy transition	ARDL / NARDL	Renewable energy adoption reduces long-run emissions	Provides significant opportunities for renewable energy startups and green technology firms to expand sustainable energy infrastructure
Asymmetric environmental dynamics	NARDL	Positive and negative economic shocks affect emissions differently	Supports innovation-driven environmental strategies and entrepreneurial initiatives focused on sustainable energy solutions
Technological innovation and sustainability	NARDL / hybrid models	Green technologies reduce emissions over time	Promotes the development of clean technology enterprises and innovation-driven startups addressing environmental challenges

The literature reviewed highlights the importance of technological creativity and the need to incorporate renewable energy in attaining environmental sustainability as depicted in Table 2. The results also indicate that asymmetric econometric models offer more insightful knowledge on the effects of economic

shocks on the environment. These insights have significant implications regarding sustainable entrepreneurship because they point to the fact that novel business frameworks and technological solutions are necessary, which assist in the process of shifting towards low-carbon economic frameworks.

The thematic analysis shows that the development of econometric techniques in the energy-emissions literature represents the trends of the general structural shifts that are taking place in the contemporary energy systems. With the shift toward renewable energy sources and sustainable production types, entrepreneurial inventions and technological development become more and more significant in determining the environmental results. The dynamics are thus critical to the development of policies that promote sustainable entrepreneurship and at the same time deal with environmental issues that come with economic growth.

5. COMPARATIVE ANALYSIS AND IMPLICATIONS FOR SUSTAINABLE ENTREPRENEURSHIP

5.1 Divergence in Empirical Findings

The comparative evaluation of the literature examined demonstrates significant variation of the empirical results of the studies based on the use of the linear econometric models, and unbiased non-linear asymmetric models. Linear models, especially the ARDL and VECM are usually used to estimate average relationships in the long-run between economic growth and energy consumption and environmental indicators. The models have been instrumental in establishing the macroeconomic connexion between energy consumption and carbon emissions in India and other developing economies (Saidi and Hammami, 2015; Sebri and Ben-Salha, 2014). As equilibrium relationships are concerned, the linear models can be helpful in the overall understanding of the environmental impact of fossil fuel-based economic development.

Nevertheless, an increasing amount of literature shows that symmetric econometric models can hide critical structural processes in the transforming energy systems. Non-linear modelling, including the NARDL modelling, has disclosed that indicators environmental tend to significantly react to positive and negative economic shocks in a different manner. As an example, the rise in energy consumption can be associated with a rapid rise in emissions, whereas the fall in energy consumption can be associated with a corresponding fall being less than one due to technological inertia or structural rigidities in the energy industry. Recent asymmetric modelling studies have confirmed empirically that positive and negative changes to energy use and economic variables may have radically different effects on the environment (Mujtaba et al., 2021; Şanlili et al., 2023). This deviation shows the significance of selecting methods of interpretation of the energy emissions nexus and appraising sustainability policies.

Within the framework of sustainable entrepreneurship, the implications of these findings are that technological innovation and entrepreneurial action is an important factor in determining environmental outcomes. As the economies shift to renewable energy infrastructure and environmentally friendly production system, entrepreneurs and green technology companies can play a big role in determining the pace and efficiency of the change. As a result, methodological frameworks that can reflect asymmetric adjustments can give more realistic data on the role of innovation and entrepreneurship in the sustainable development of the economy.

5.2 Methodological Trade-offs Between Linear and Non-Linear Models

Although both linear and non-linear econometric methods help to discuss the energy emissions nexus, each paradigm has its own methodological pros and cons. Linear models are simple and easy to interpret which makes them especially handy in establishing the relationship between macroeconomic variables in long-run equilibrium. These models also tend to be fairly robust to small datasets, and that is why they are used in numerous early empirical studies investigating the environmental sustainability in developing economies.

On the contrary, non-linear econometric models offer more analytical flexibility because they include asymmetric reaction to economic shocks. These models enable the investigators to examine the reaction of environmental indices to varied circumstances in cases of economic growth and recession. The asymmetric economicetrics models, especially NARDL model, have allowed the researchers to break the economic variables down into positive and negative changes and analyse their unique environmental impact (Shin et al., 2014). The non-linear models do not only demand more sophisticated estimation processes and data, but they also give a better understanding of the structural changes that take place in the current energy systems (Mujtaba and Jena, 2021). Empirical experiences of asymmetric modelling strategies illustrate that the economic growth, energy use, and other macroeconomic measures can have various environmental outcomes to various changes

To explain these methodological differences, the key features of the linear and non-linear econometric models are outlined in Table 3. The table brings out the major assumptions, analytical abilities, and policy implications with each approach. The given comparison demonstrates how asymmetric econometric models can have a more refined understanding of sustainability changes and technological innovation in changing energy markets.

Table 3: Comparative Assessment of Econometric Approaches Used in Energy–Emissions Nexus Studies

Criteria	Linear Models (ARDL / VECM)	Non-Linear Models (NARDL / Asymmetric Models)
Core assumption	Symmetric response to increases and decreases in explanatory variables	Asymmetric response to positive and negative shocks
Analytical focus	Long-run equilibrium relationships	Dynamic and asymmetric adjustments
Data requirements	Suitable for relatively small time-series datasets	Typically requires larger datasets
Model complexity	Relatively simple estimation and interpretation	More complex estimation procedures
Ability to capture structural change	Limited ability to capture structural shifts	Strong capacity to capture structural transformations
Policy insights	General macroeconomic policy guidance	Detailed insights for targeted environmental policies
Relevance for sustainability transition	Identifies overall relationship between energy and emissions	Explains how technological innovation and energy transitions influence emissions
Implications for sustainable entrepreneurship	Highlights need for cleaner energy systems	Identifies opportunities for green innovation and renewable energy enterprises

The main difference between the two methodological approaches is how they deal with economic shocks as demonstrated in Table 3. Linear models make equal adjustments whereas non-linear models implicate unequal adjustments and structural changes. These variations are especially relevant in the case of economies that are still in a rapid transition due to technological change and energy transition.

5.3 Policy and Entrepreneurial Implications for Sustainable Development

The identified methodological differences presented in the comparative analysis are significant implications of sustainability policy and entrepreneurial development in emerging economies. Econometric models of linear nature give us our understanding of the general correlation between economic growth and environmental degradation which can inform macroeconomic policy strategies. Nonetheless, asymmetric models provide more information on the responsiveness of environmental results to technological innovation, policy interventions and structural economic transformation.

To policy makers, the results imply that environmental policies ought to take into account the asymmetric behaviour of economic activities and environmental activities. The environmental impact of economic growth can be mitigated through policies favouring the use of renewable energy and energy efficiency as well as the use of green technology. Meanwhile, to enhance the process of switching towards low-carbon economic systems, it is critical to help the growth of the entrepreneurial ecosystem that will encourage sustainable innovation. Sustainability-oriented business model research indicates the significance of both institutional and policy environments in the context of motivating the firm to implement environmentally responsible strategies of innovation (Schaltegger et al., 2016).

Sustainable entrepreneurship is very vital in this transition as it involves coming up with new solutions that minimise the environmental effects and at the same time ensure competitiveness in the economy. The emergence of renewable energy firms, clean technology firms and energy efficient manufacturing firms can be regarded as key drivers of sustainable development in an emerging economy like India. The research on sustainable entrepreneurship highlights that entrepreneurs are the key players in the process of finding opportunities in the environment and converting them into feasible business patterns to generate economic and ecological value (Belz & Binder, 2017). Moreover, the establishment of entrepreneurial ecosystems that will promote green innovation may have a significant impact on sustainable technologies adoption. Institutional support, environmental awareness, and the presence of market opportunities of green innovation tend to influence the development of entrepreneurial intentions and motivations towards sustainability-oriented ventures (AkVuorio et al., 2018). Through combining the learning of new and sophisticated econometric models and policy programmes that facilitate the entrepreneurial innovation, governments have the capacity to provide an enabling environment to ensure sustainable economic development.

The comparative analysis points out that the development of methodologies in environmental economics is strongly associated with structural changes in the energy systems. Due to the growing focus on sustainability and technological change in

the economy, analytic frameworks that are able to explain asymmetric dynamics will be of greater importance to comprehend the complicated relationship between economic development, environmental sustainability, and entrepreneurial transformation.

6. DISCUSSION AND FUTURE RESEARCH DIRECTIONS

This research demonstrates that there has been a profound methodological shift in the empirical literature review on the relationship between energy use, economic development and carbon emission. Previous studies mainly used symmetric econometric models like the ARDL and the VECM to estimate the long term relationship between macroeconomic variables and environmental variables. These models were valuable in illuminating the relationship between economic growth and energy consumption and environmental degradation in the developing economies (Acheampong, 2018; Ito, 2017). Nevertheless, thematic and comparative study analysis in this work indicates that such symmetric models might not be entirely effective in the dynamic nature of contemporary energy systems, especially in those economies where technological and structural change is occurring rapidly.

Further recent research work utilises non-linear econometric models more extensively including the NARDL model which enables researchers to model asymmetric reactions to economic shocks. These models understand that growth and decline of economic variables do not always produce environmental results in an equal measure (Ahmed et al., 2023; Shastri et al., 2020). As an example, it is possible that rapid growth in emissions may follow increases in energy consumption whereas modest decreases in emissions may not follow a corresponding decrease in energy use because of technological inertia, infrastructural restrictions or behaviour. The use of asymmetric modelling models is consequently a significant shift in the methodology of environmental economics studies allowing researchers to examine the issue of sustainability with increased analytical accuracy.

The findings of this review also highlight a rise in the role of technological innovation and structural change in determining environmental sustainability. The experimental data has shown that the adoption of renewable energy and energy efficiency aspects as well as technological advances significantly contribute to the reduction of environmental degradation (Balsalobre-Lorente et al., 2018; Ulucak and Khan, 2020; Rahman and Vu, 2020). These conclusions imply that sustainable economic development is not only about environmental regulation but also about innovation-oriented solutions that will help to change traditional systems of energy into more sustainable and efficient ones (Qayyum et al., 2021; Haseeb et al., 2024). Sustainable entrepreneurship, in this regard, becomes one of the key processes according to which the technological innovation could be transformed into the practical environmental solutions.

Innovation in other areas like renewable energy, green technology, and energy-efficient production can impact a lot on the sustainability of the environment. Green technology ventures, renewable energy startups, and energy management are also valuable elements of new ecosystems of entrepreneurs that favor environmental sustainability. Entrepreneurial activities can help solve the carbon emission problem and create new working and economic opportunities by encouraging innovations in these areas (Gast et al., 2017; Muñoz and Cohen, 2018). The innovative business and clean technology start-ups can be instrumental in expediting the process of sustainability transition in a country like India where the energy requirement remains to be high and the environmental issues persist.

The shift to the greener energy systems also gives the policymakers a chance to sponsor the environmentally-friendly innovation (Rao & Haq, 2023). Government programmes encouraging investment in renewable energy and technological research, sustainable infrastructure can help to provide an enabling environment to entrepreneurship. Financial incentives and research grants, as well as innovation incubators, are some of the policies that can be used to speed up the implementation and creation of sustainable technologies (Tamvada, 2020; Caramizaru and Uihlein, 2020). These interventions are specifically essential when it comes to the emerging economies, where the rising rates of industrialization and urbanisation still raise the energy needs and strains on the environment.

Although there has been an increase in literature on the energy-emissions nexus, there are still a few gaps in the research. A significant part of the literature uses annual macroeconomic data series on time-series, which tends to mask the temporary changes in the dynamics of energy use and emissions. Higher frequency data, including quarterly or monthly data points, would be useful to future research to better represent the effects of policy changes, economic shocks as well as technological innovation (Itoo and Ali, 2023). Moreover, the disaggregated studies of coal, oil, natural gas, and renewable energy might offer more accurate data on the environmental effects of energy transitions.

The combination of old-fashioned economic methods with new data analysis methods like machine learning and sophisticated data analytics could also be applied in future research too to enhance the level of prediction and take into account intricate non-linear relationships. Moreover, the connexion between the institutional quality, policy frameworks, and entrepreneurial ecosystems and their impact on

sustainability results can potentially shed additional light on how entrepreneurial innovation facilitates environmental sustainability.

The results highlight the significance of methodological creativity and cross-disciplinary studies with a view of developing sustainability research. The combination of the knowledge of environmental economics and the study of entrepreneurship can be used to understand how the contribution of innovation-based businesses and sustainable business models to the survival of the environment and the economic progress of the long term.

7. CONCLUSION

This study examined the methodological evolution in the empirical literature analyzing the relationship between energy consumption, economic growth, and carbon emissions in India. By systematically reviewing studies employing both linear and non-linear econometric approaches, the research highlights how methodological choices shape the interpretation of the energy–emissions nexus. Traditional linear models, particularly the ARDL and VECM, have played an important role in establishing the long-run relationship between energy consumption, economic growth, and environmental degradation in developing economies. However, the review shows that symmetric frameworks may not fully capture the complex and dynamic nature of modern energy systems. More recent studies increasingly adopt non-linear approaches, especially the NARDLmodel, which identifies asymmetric responses to economic shocks and provides a more nuanced understanding of environmental outcomes. The findings also underline the importance of technological innovation, renewable energy adoption, and sustainable entrepreneurship in addressing environmental challenges. In the context of India and other emerging Asian economies, green enterprises, renewable energy ventures, and innovation-driven business models can play a central role in accelerating the transition toward low-carbon development. These entrepreneurial initiatives support the diffusion of clean technologies, create new economic opportunities, and strengthen environmentally responsible business practices. Overall, the study highlights the need for continued methodological innovation and interdisciplinary research to better understand sustainability transitions in emerging economies.

REFERENCES

1. Acheampong, A. O. (2018). Economic growth, CO2 emissions and energy consumption: what causes what and where?. *Energy economics*, *74*, 677-692.
2. Ahmad, M., Khan, Z., Ur Rahman, Z., & Khan, S. (2018). Does financial development asymmetrically affect CO2 emissions in China? An application of the nonlinear autoregressive distributed lag (NARDL) model. *Carbon Management*, *9*(6), 631-644.
3. Ahmed, M., Huan, W., Ali, N., Shafi, A., Ehsan, M., Abdelrahman, K., ... & Fnais, M. S. (2023). The effect of energy consumption, income, and population growth on CO2 emissions: Evidence from NARDL and machine learning models. *Sustainability*, *15*(15), 11956.
4. Akalpler, E., & Hove, S. (2019). Carbon emissions, energy use, real GDP per capita and trade matrix in the Indian economy-an ARDL approach. *Energy*, *168*, 1081-1093.
5. AkVuorio, A. M., Puumalainen, K., & Fellnhofer, K. (2018). Drivers of entrepreneurial intentions in sustainable entrepreneurship. *International Journal of Entrepreneurial Behavior & Research*, *24*(2), 359-381.
6. Apergis, N., & Payne, J. E. (2015). Renewable energy, output, carbon dioxide emissions, and oil prices: evidence from South America. *Energy Sources, Part B: Economics, Planning, and Policy*, *10*(3), 281-287.
7. Awodumi, O. B., & Adewuyi, A. O. (2020). The role of non-renewable energy consumption in economic growth and carbon emission: Evidence from oil producing economies in Africa. *Energy Strategy Reviews*, *27*, 100434.
8. Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., & Farhani, S. (2018). How economic growth, renewable electricity and natural resources contribute to CO2 emissions?. *Energy policy*, *113*, 356-367.
9. Belz, F. M., & Binder, J. K. (2017). Sustainable entrepreneurship: A convergent process model. *Business strategy and the environment*, *26*(1), 1-17.
10. Ben Jebli, M., & Ben Youssef, S. (2017). Renewable energy consumption and agriculture: evidence for cointegration and Granger causality for Tunisian economy. *International Journal of Sustainable Development & World Ecology*, *24*(2), 149-158.
11. Caramizaru, A., & Uihlein, A. (2020). *Energy communities: an overview of energy and social innovation* (Vol. 30083). Luxembourg: Publications Office of the European Union.
12. Chukwunonso Bosah, P., Li, S., Kwaku Minua Ampofo, G., Akwasi Asante, D., & Wang, Z. (2020). The nexus between electricity consumption, economic growth, and CO2 emission: An asymmetric analysis using nonlinear ARDL and nonparametric causality approach. *Energies*, *13*(5), 1258.
13. Gast, J., Gundolf, K., & Cesinger, B. (2017). Doing business in a green way: A systematic review of the ecological sustainability entrepreneurship literature and future research directions. *Journal of cleaner production*, *147*, 44-56.

14. Haseeb, M., Kayani, U., Shuaib, M., Hossain, M. E., Kamal, M., & Khan, M. F. (2024). Asymmetric role of green energy, innovation, and technology in mitigating greenhouse gas emissions: evidence from India. *Environmental Science and Pollution Research*, *31*(15), 23146-23161.
15. Ito, K. (2017). CO2 emissions, renewable and non-renewable energy consumption, and economic growth: Evidence from panel data for developing countries. *International Economics*, *151*, 1-6.
16. Itoo, H. H., & Ali, N. (2023). Analyzing the causal nexus between CO2 emissions and its determinants in India: Evidences from ARDL and EKC approach. *Management of Environmental Quality: An International Journal*, *34*(1), 192-213.
17. Karedla, Y., Mishra, R., & Patel, N. (2021). The impact of economic growth, trade openness and manufacturing on CO2 emissions in India: an autoregressive distributive lag (ARDL) bounds test approach. *Journal of Economics, Finance and Administrative Science*, *26*(52), 376-389.
18. Khan, Y., Khan, M. A., & Zafar, S. (2023). Dynamic linkages among energy consumption, urbanization and ecological footprint: empirical evidence from NARDL approach. *Management of environmental quality: an international journal*, *34*(6), 1534-1554.
19. Khan, Y., Khan, M. A., Zafar, S., & Shahzeb, S. M. (2026). Mitigating emissions in India: an asymmetric perspective on fossil fuel use. *International Journal of Energy Sector Management*, *20*(2), 448-471.
20. Leitão, N. C. (2014). Economic growth, carbon dioxide emissions, renewable energy and globalization. *International Journal of Energy Economics and Policy*, *4*(3), 391-399.
21. Mardani, A., Streimikiene, D., Cavallaro, F., Loganathan, N., & Khoshnoudi, M. (2019). Carbon dioxide (CO2) emissions and economic growth: A systematic review of two decades of research from 1995 to 2017. *Science of the total environment*, *649*, 31-49.
22. Mujtaba, A., & Jena, P. K. (2021). Analyzing asymmetric impact of economic growth, energy use, FDI inflows, and oil prices on CO2 emissions through NARDL approach. *Environmental Science and Pollution Research*, *28*(24), 30873-30886.
23. Muñoz, P., & Cohen, B. (2018). Sustainable entrepreneurship research: Taking stock and looking ahead. *Business strategy and the environment*, *27*(3), 300-322.
24. Neog, Y., & Yadava, A. K. (2020). Nexus among CO2 emissions, remittances, and financial development: a NARDL approach for India. *Environmental Science and Pollution Research*, *27*(35), 44470-44481.
25. Ohlan, R. (2015). The impact of population density, energy consumption, economic growth and trade openness on CO2 emissions in India. *Natural Hazards*, *79*(2), 1409-1428.
26. Pachiyappan, D., Ansari, Y., Alam, M. S., Thoudam, P., Alagirisamy, K., & Manigandan, P. (2021). Short and long-run causal effects of CO2 emissions, energy use, GDP and population growth: evidence from India using the ARDL and VECM approaches. *Energies*, *14*(24), 8333.
27. Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*, *16*(3), 289-326.
28. Qayyum, M., Ali, M., Nizamani, M. M., Li, S., Yu, Y., & Jahanger, A. (2021). Nexus between financial development, renewable energy consumption, technological innovations and CO2 emissions: the case of India. *Energies*, *14*(15), 4505.
29. Rahman, M. M., & Vu, X. B. (2020). The nexus between renewable energy, economic growth, trade, urbanisation and environmental quality: A comparative study for Australia and Canada. *Renewable Energy*, *155*, 617-627.
30. Rao, G. B., & Haq, A. (2023). CO2 emissions, economic growth and energy consumption nexus: the case of India. *Theoretical and Applied Economics*, *30*(4), 63-76.
31. Sahu, N. C., & Kumar, P. (2020). Impact of globalization, financial development, energy consumption, and economic growth on CO2 emissions in India: Evidence from ARDL approach. *Journal of Economics Business and Management*, *8*(3), 257-270.
32. Saidi, K., & Hammami, S. (2015). The impact of energy consumption and CO2 emissions on economic growth: Fresh evidence from dynamic simultaneous-equations models. *Sustainable Cities and Society*, *14*, 178-186.
33. Şanlı, D., Muratoğlu, Y., Songur, M., & Uğurlu, E. (2023). The asymmetric effect of renewable and non-renewable energy on carbon emissions in OECD: new evidence from non-linear panel ARDL model. *Frontiers in Environmental Science*, *11*, 1228296.
34. Schaltegger, S., Hansen, E. G., & Lüdeke-Freund, F. (2016). Business models for sustainability: Origins, present research, and future avenues. *Organization & environment*, *29*(1), 3-10.
35. Sebri, M., & Ben-Salha, O. (2014). On the causal dynamics between economic growth, renewable energy consumption, CO2 emissions and trade openness: Fresh evidence from BRICS countries. *Renewable and Sustainable Energy Reviews*, *39*, 14-23.
36. Shahani, R., & Bansal, A. (2020). *An econometric investigation of dynamic linkages between CO_2 emissions, energy consumption, economic*

growth: A case of India and China (MPRA Paper No. 103591). Munich Personal RePEc Archive.
37. Shastri, S., Mohapatra, G., & Giri, A. K. (2020). Economic growth, renewable and nonrenewable energy consumption nexus in India: evidences from nonlinear ARDL approach and asymmetric causality analysis. *International Journal of Energy Sector Management*, *14*(4), 777-792.
38. Shin, Y., Yu, B., & Greenwood-Nimmo, M. (2014). Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In *Festschrift in honor of Peter Schmidt: Econometric methods and applications* (pp. 281-314). New York, NY: Springer New York.
39. Sinha, A., & Shahbaz, M. (2018). Estimation of environmental Kuznets curve for CO2 emission: role of renewable energy generation in India. *Renewable energy*, *119*, 703-711.
40. Sreenivasan, A., & Suresh, M. (2024). Energizing innovation: a bibliometric exploration of renewable energy entrepreneurship. *Journal of Responsible Production and Consumption*, *1*(1), 177-205.
41. Tamvada, M. (2020). Corporate social responsibility and accountability: a new theoretical foundation for regulating CSR. *International Journal of Corporate Social Responsibility*, *5*(1), 2.
42. Ulucak, R., & Khan, S. U. D. (2020). Determinants of the ecological footprint: role of renewable energy, natural resources, and urbanization. *Sustainable Cities and Society*, *54*, 101996.