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Review

Nudging Sustainable Development: Reviewing Energy Transition and Economic Development

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Abstract: Recently, as more countries and regions have embarked on the path of energy transition, the speed and manner of economic development have been influenced in varying degrees. However, the relationship between energy transition and economic development remains unclear, as research conclusions are inconsistent. The aim of this study is to systematically examine the relationship between energy transition and economic development using the literature review approach. This study selected 102 studies from Scopus that explicitly address energy transition and economic development as our final sample for this investigation, aiming to clarify the current research status on factors, barriers, and pathways of energy transition, and discuss related theories about energy transition. The results indicate a significant increase in research volume on this topic over the past four years, with nearly half of the studies focusing on cross-regional countries or economic entities. The sampled literature reveals various relationships between economic development and energy transition, including one-way promotion, one-way inhibition, bidirectional causality, and ineffectiveness. Factors influencing energy transition include technology, financial support, environmental governance, human capital, taxation, rents, and foreign direct investment (FDI). The main obstacles to energy transition lie in the scarcity of environmental resources, path dependence, and uneven development. Based on these research findings, this study discusses prospects and potential directions for future studies.

Keywords: economic development; energy transition; energy transition barrier; energy transition consequences; energy transition determinants

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Citation: Tian, X.; Kohar, U.H.A.; Khatib, S.F.A.; Wang, Y. Nudging Sustainable Development: Reviewing Energy Transition and Economic Development. *Sustainability* **2024**, *16*, 3101. https://doi.org/10.3390/su16083101

Academic Editor: Barry D. Solomon

Received: 14 February 2024
Revised: 1 April 2024
Accepted: 2 April 2024
Published: 9 April 2024

1. Introduction

In contemporary society, energy has become one of the most basic factors of production. Energy is a vital driving force for the survival and development of any country or sector, a fundamental factor that is evident not only in developing nations but also in developed countries or regions [1–3]. Energy is a basic asset in enabling socioeconomic development in any country [4]. Due to the diverse geographical environments of different countries, their energy infrastructure and conditions vary greatly, even in a long and serious energy crisis [5], leading to distinct energy strategies [6–8]. However, it is undeniable that over the past two decades, the rapid development of BRICS countries has contributed significantly to the global surge in carbon emissions [9,10]. As the need for decoupling economic growth from energy consumption intensifies, some developing nations find themselves at a point where comprehensive adjustments to their energy structure are imperative, prompting a comprehensive push for energy and economic decoupling whether they are willing or not [11,12].

From a global perspective, the global economy is predominantly powered by fossil fuels, with energy being the most critical sector and factor influencing economic development [13,14]. Global energy-related industries account for 68% of carbon emissions, with 44% stemming from non-renewable sources [15]. Regionally, the ASEAN region stands as the largest energy consumer globally, representing 44% of global consumption and serving as a significant pillar for global economic development [15]. Moreover, different countries adopt varying renewable energy sources in their energy transition processes, necessitating rational choices based on their own resource endowments and economic conditions [16]. China has made great achievements since its reform and opening up, especially the rapid growth of the industrial sector at the cost of high energy input, high energy consumption, and high emissions for a long period of time [17,18]. Nepal can leverage its inherent advantage in hydropower to achieve energy transition while fostering economic development, simultaneously meeting the rising energy demands of the South Asian region while boosting domestic consumption [16]. Thus, finding a way to secure energy supply, adjust the energy supply structure, and improve energy efficiency without compromising the pace of sustainable economic development becomes an important task on the road to future development.

The term "economic growth" refers to the continuous increase in the level of economic output in a country or region over a period of time [10,19], while the concept of "economic development" is more comprehensive [20]. Considering the literature related to energy transition, the distinction between the two has not been strictly made, with GDP or per capita GDP used as indicators of economic development [21–23]. Therefore, in this study, both terms refer to the level of economic output of a region or country. Energy transition refers to the fundamental change of the energy structure on the energy supply side [9,24]. The motivation behind this study is to achieve the primary research objective of clarifying the relationship between energy transition and economic development.

In the past two decades, there are more than sixty-thousand researches on "energy transition". Unfortunately, most of the literature focuses on the characteristics of the different energy sources themselves, and research articles in the economics, econometrics, and finance fields are growing to hundred papers in recent years [14,25,26]. It was found in [5] that in the process of global economic development, emerging economies such as China and India have been driving the world's energy demand upwards. Scholars have begun to incorporate an increasing number of factors into their considerations, utilizing past data to explore the relationship between energy transition and economic growth [27,28], the application of new energy sources, and other elements influencing regional economic development [22,29,30]. Furthermore, factors such as foreign direct investment (FDI), domestic trade, domestic financial development, and the growth of the digital economy have varying degrees of influence on a country's energy transition and emissions [8,17,31–33].

It was found in [6] that FDI decreased the overall use of renewable energy, but higher economic growth promotes energy transformation. It was discovered in [34] that the FDI inflows reduce the renewable energy levels within European Union members. Because of the advantages of renewable energy, India and China have also made significant investments in Nepal [5]. It was determined in [35] that renewable electricity output and economic growth promote energy transition in the USA, however, economic growth does not always go hand-in-hand with a positive energy transition [36]. Additionally, there is a long-run and unidirectional causality relationship between economic growth and energy consumption [37,38]. Some scholars have taken a forward-looking approach, exploring the potential energy transition paths and strategies for one or multiple regions in the future, as well as the adjustments and impacts involving different sectors during the transition, including the phenomenon of decoupling from the economy [3,39–44]. A possible reason for this is that the energy transition leads to certain costs.

Therefore, amidst the prevailing trend of energy transition, it becomes increasingly urgent for countries and regions with varying resource endowments, industrial structures, and levels of development to strike a balance between economic growth and energy transition. It is essential for them to explore their own paths towards green and sustainable transformation and development [5,16,45]. Due to variations in estimation methods, research strategies, regional characteristics, and data periods, the conclusions drawn have not been consistent.

Previous literature described energy efficiency [46–48], energy policy [26,49,50], and emission control [51,52], but have not thoroughly investigated a wider agenda for future research. This study focuses on the individual influencing factors and mutual interactions of energy transition and economic development, employing a systematic literature review approach to comprehensively analyze the literature on this field. The objectives are:

1. To examine the current global research trends in energy transition and economic development.
2. To discuss the related theory about energy transition.
3. To identify the factors, barriers, pathway, and outcomes of energy transition.

The systematic literature review is a widely used, well-established, and systematic research method, highly suitable for focusing on a specific topic. Through this study, we aim to explore, categorize, analyze, conduct meta-analyses, and synthesize evidence to present a more comprehensive view of the chosen field's subject matter. This approach allows us to map out the research landscape, identify research gaps, and propose future research directions [13,53,54]. Hence, a systematic literature review is needed to discover new research areas and summarize developed countries' experiences of sustainable economic development in the process of energy transition in the world, so as to contribute to the realization of the dual goals of energy transition and economic development in many developing countries. This study presents a comprehensive and systematic review of the research in the field of energy transition and economic development by systematically analyzing a substantial body of previous research findings. The contributions of this study include the following. Considering the lack of focused review studies on this topic in the past, we believe this study will provide a clear roadmap for future research, identifying key research directions and themes. This will contribute to promoting further in-depth development in this area and bridging knowledge gaps. Moreover, the study explores the theoretical developments related to this topic, going beyond merely examining the environmental Kuznets curve hypothesis. It delves into the joint research of certain economic development theories and energy transition theories, highlighting emerging theories in this field. From a practical perspective, this research offers a broad set of findings on energy transition that can be applied to countries and regions worldwide with varying characteristics, resource endowments, cultural traditions, and industrial structures. In the process of energy transition, members of government and policymakers can advance elements that facilitate energy transition based on the research findings of this study such as technological progress, financial support, and environmental governance, while also avoiding obstacles to energy transition by considering their own resource endowments, enhancing government effectiveness, management capabilities, and transparency. By focusing on the intricate relationship between energy transition and economic development, these nations and regions can better determe their own energy transition paths.

This research has certain limitations. Firstly, despite our best efforts and the use of standard methods and procedures, it is possibile that some relevant literature and related knowledge may not have been included. Secondly, to expand the scope of the search, future studies could consider including multiple databases from Web of Science. Lastly, future research can explore the impact of different energy transitions on the future development of research subjects at the sectoral, corporate, household, and individual levels. Additionally, focusing on newer research concepts such as carbon footprint, digital development, and other factors that can improve the environment and influence economic development would be beneficial.

The subsequent structure of this study is arranged as follows. Section 2 presents the methodology adopted in the review process and outlines the research strategy, Section 3 shows the review findings, Section 4 discusses the limitations of previous research and future research roadmap, and Section 5 concludes the study.

2. Research Methodology

This study follows the standard SLR process outlined in [13,53,55]. Firstly, we chose Scopus as the database to search for the existing publications on "energy transition" and "economic development" and try to get robust reviews of relevant studies regardless of time-period or journal. Scopus database is the largest abstract indexing database and delivers the broadest coverage of any interdisciplinary abstract and citation database. Scopus uniquely combines a comprehensive, expertly curated abstract and citation database with enriched data and linked scholarly literature across a wide variety of disciplines. Scopus database also provides advanced searching options which could be used to form better searching strategies with accurate results, especially in spread fields. The purpose of the part Is to map the way of what theories or themes have been discussed and identify the gaps by investigating the themes.

2.1. Sample Identification

In this study, we implemented a keyword-based strategy for sample identification and literature search [13,56]. In order to collect all the related publications and studies, we formed a searching string about energy structure change and economic development. Considering that "energy transformation" and "energy transition" are both used as energy structure transformation, this study used a searching string that includes the following terms: "energy transformation", "energy transition", "low carbon", "economic grow", "economic growth", "economic development", and "economic develop". The search focused on "article title-abstract-keywords" to ensure comprehensiveness while minimizing the retrieval of unrelated publications. The keywords for energy transition were selected after reviewing some other studies [9,13]. The final search string is presented in Figure 1.

2.2. Inclusion and Exclusion Criteria

The initial search of the aforementioned keywords led to 4133 results, including articles, books, conference papers, reviews, etc. Then, we followed the standard inclusion and exclusion criteria [54,55] and limited the results to "English", reducing the results to 3885 documents. Then, the result was narrowed down to journal articles only, resulting in a total of 2727 documents. Some of these results delve into technologies related to energy transition, innovations in materials science, and other disciplines with low relevance to economic development. This study does not focus on specific energy technologies and efficiency topics but instead examines the relationship between energy transition and economic development from a global and broader perspective. Hence, 19 unrelated disciplines such as "Health", "Neuroscience", "Nursing", "Veterinary", "Immunology and Microbiology", "Psychology", "Arts and Humanities", "Biochemistry, Genetics and Molecular Biology", "Pharmacology, Toxicology and Pharmaceutics", "Chemistry", "Physics and Astronomy", "Materials Science", "Chemical Engineering", "Agricultural and Biological Sciences", "Medicine", "Mathematics", "Earth and Planetary Sciences", "Computer Science" and "Decision Sciences" were excluded. The search was further refined to include only subjects related to "Environmental Science", "Energy", "Social Sciences", "Economics, Econometrics and Finance", "Engineering", "Business, Management and Accounting", and "Multidisciplinary", resulting in 1828 studies. After screening the title of the publications, studies which are not focused on energy transition and economic growth were excluded, leaving a total of 171 publications. Eventually, we deleted five low-quality studies which have not been cited by any research within two years of publication, decreasing the number to 166. This study is not limited to a specific journal or period, as our aim is to investigate the holistic development of the field and present findings from a comprehensive and complete selection of papers from this emerging area of study.

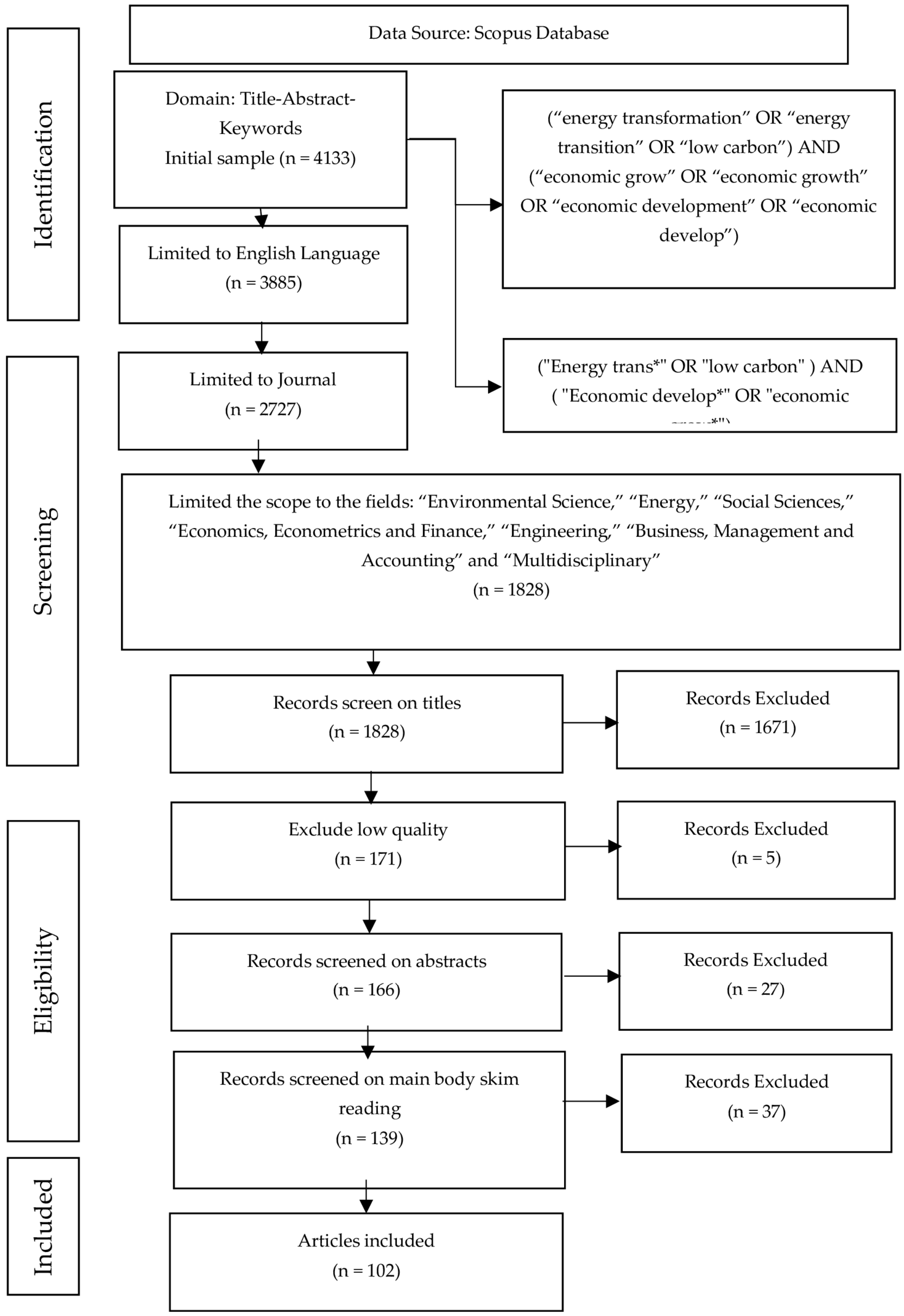

Figure 1. Process of searching literature.

Then, one of our researchers screened all the title and abstracts of the remaining publications and discarded the literatures that were irrelevant to the topic. Subsequently, another author independently re-examined the eliminated studies, resulting in the number of remaining literatures dropping to 139. The last step of eligibility screening was reading the main body of documents left and deleting those deemed irrelevant, which resulted in there being only 102 articles in the end. Similar to other scholars [55], this review focuses on the annual trends of the sample literature publications, previous research methods, research models, relevant theories, and the themes of discussion. Figure 1 presents the process of choosing the database, keywords, searching strategy, and screening criteria used in this review research. Unlike other exiting literature reviews about energy transition [57,58], we used a systematic method which is not solely focused on "energy transition", but also on "economic development".

3. Results

3.1. Temporal Trend of Publications

Through the annual publication statistics Figure 2, it is evident that research on energy transition and economic development has been ongoing for nearly three decades. However, there is a noticeable trend of "fewer publications initially, followed by a surge in later years", indicating fluctuating interest in the subject. The earliest research in our sample was published in 1996 and focused on the United States [46], illustrating that developed countries paid early attention to the relationship between energy transition and economic development. This pattern aligns with historical development trends. Prior to 2015, not only was the annual publication volume on this topic limited to a maximum of one search, but there were also several years with no publications at all, indicating that people did not consider the relationship between energy transition and economic development as a research topic. The situation changed significantly after 2016 when the "Paris Agreement" was implemented, providing a unified framework for global actions in response to climate change beyond 2020. Since 2016, scholars have shown increased attention to this subject, with researchers exploring it yearly. However, the overall number of publications per year remained relatively low, ranging from four to five research articles. This could be attributed to the fact that some countries already achieved energy transition, while others are still in the process. Starting from 2020, there was a remarkable surge in the number of annual publications related to this topic, escalating from single-digit figures to a peak of 34 research articles in 2023. Moreover, it is worth noting that the number of publications in 2023 only represents data from the first seven months of the year, suggesting a likelihood of more than a twofold increase in the total number of publications for the entire year compared to the previous year.

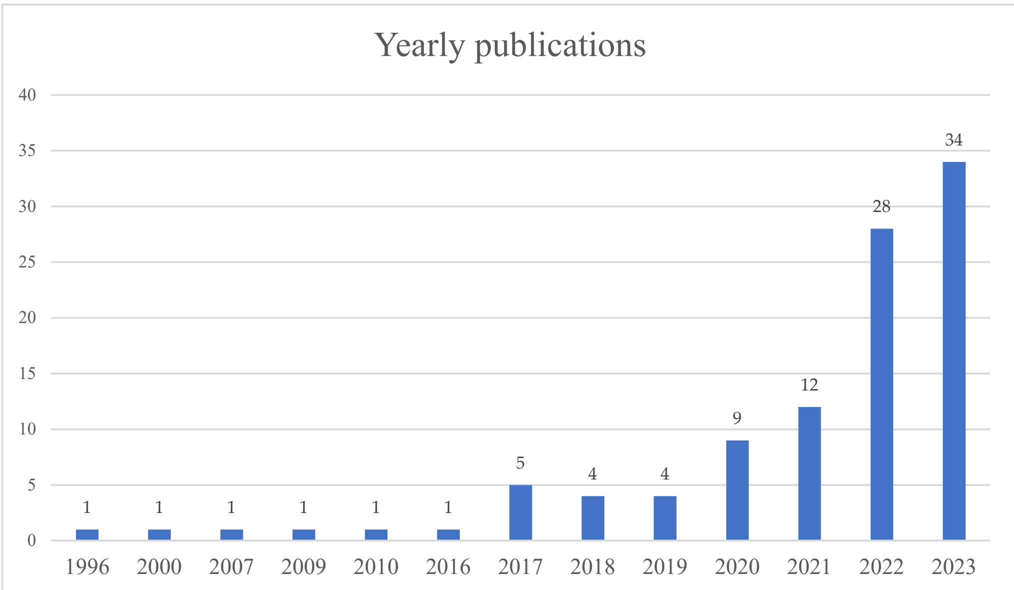

Figure 2. Number of studies per year.

3.2. Geographical Distribution

This research considers the fact that many studies have used research subjects from different regions, countries, and continents. As a result, studies covering two or more countries have been summarized according to their research subjects, rather than being grouped by individual countries. Therefore, the first half of Table 1 does not present a summary based on individual countries. It can be observed that nearly a quarter of the studies conducted over the years focused on multiple countries worldwide. Among them, some studies categorized countries based on their economic development [59,60], while others focused on the top 10 manufacturing countries [61]. Some specifically investigated countries with better green transformations [62]. The second-ranked regions are the European Union and Africa. The number of studies concerning the EU region has remained relatively stable over the years, while a significant increase in research related to Africa has occurred in the past two years. This indicates that the developed EU region has been paying continuous attention to energy transition and economic development, whereas the less developed regions in Africa have only begun to show interest in this matter. Asia, the E7 member countries, the OECD countries, and the BRICS nations have also shown a gradual increase in attention to this issue, likely due to their similar regional contexts, development trajectories, or shared interests.

From literature focused on individual countries or regions as research subjects, China undoubtedly stands out as the most extensively studied economy in this field, with a total of 26 publications. This number exceeds the total number of publications that have a global scope as their research focus, indicating that China places significant emphasis on the impact of energy transition during its economic development process. Furthermore, some of these research articles have a more specific focus, delving into research at the provincial or regional level [18,24,40,63]. The United States, India, Tunisia, and Bangladesh have each contributed more than one publication as individual countries. However, for 13 countries or regions (such as Korea, Pakistan, Spain, Germany, and Argentina) the number of publications focused on them as research subjects is limited to one. Overall, the number of countries or regions showing interest in this issue remains relatively low, and there is a trend towards multi-country and clustered research. This highlights the need for further cross-national investigations, as they would be more conducive to elucidating the general patterns and differentiated impacts of economic development and energy transition across a broader range of economies with diverse characteristics. The United States, Germany, China, the European Union, and Australia have been identified as major participants in energy transition research [13].

Table 1. Reginal distribution of sample studies.

Geography	Pre-2015	2016–2019	2020	2021	2022	2023	Total
Global	1	4	5	2	4	7	23
European		2	2	1	1	2	8
Africa	1				3	4	8
Asian			1	1		2	4
Middle East						1	1
E7 countries					1	2	3
G7 countries						3	3
OPEC organizations				1			1
OECD organizations					3	1	4
BRICS countries					1	2	3
China	2	4		1	12	7	26
India	1	1		1			3
USA	1				1	1	3
Tunisia					1	1	2
Bangladesh				1	1		2
Others *	0	3	1	4	2	3	13

Notes: * Other countries or regions include: Korea, Taiwan, Pakistan, United Arab Emirates, Spain, UK, Germany, Bulgaria, Russia, Australia, Argentina, Algeria, and Morocco.

3.3. Research Methods and Models Distribution

From the data presented in Table 2, we can see that empirical research accounts for the largest proportion, reaching up to 80% of all samples. On the other hand, there are only three descriptive studies [64–66], and 19 studies are classified as quantitative non-empirical research, making up nearly 20% of the total. Looking at the temporal dimension, initially, non-empirical analysis dominated, comprising 60% of the research. However, the number of empirical studies gradually increased over time, doubling between 2016 and 2019. Afterward, empirical research surged far ahead, reaching its peak with thirty-three publications in 2023 while non-empirical research had only one publication that year [8]. This indicates that scholars have increasingly utilized empirical data to investigate the factors and interrelationships between energy transition and economic development. The focus has shifted from exploratory analyses to confirmatory analysis stages.

For empirical research, selecting appropriate methods or models is crucial. We classified and summarized the research methods used in past empirical studies and found that the most frequently used method is ARDL, with a total of 28 publications. The next most common method is the panel data OLS estimation, with 10 publications, followed by the MMQR method with 8 publications. Other frequently applied methods include AMG, DEA, GMM, CuP-FM/CuP-BC, Correlation, Logit, Ridge, DCCE, fsQCA, and VAR, each with more than one publication. There are also some methods that have been used in empirical analyses over the years, and those with only one research article that uses them are grouped and presented under "others" in Table 2. Looking at the temporal dimension, initially, relatively simple OLS regression and Correlation analyses were the primary approaches [46,67], however, ARDL and MMQR methods have become the mainstream research, showing a trend of increasing usage year by year. These methods are effective in capturing patterns in time-series data and avoiding biases introduced by relying solely on average values, which has led to their growing adoption among scholars [38,68–70]. With the increasing availability of longer time spans and richer datasets, future research should prioritize the use of methods or models that better reflect the characteristics of the data and allow for in-depth exploration.

Table 2. Research methods and models.

Method	Pre-2015	2016–2019	2020	2021	2022	2023	Total
Descriptive		2		1			3
Non-Empirical	3	6	2	2	5	1	19
Empirical	2	6	7	9	23	33	80
Model							
ARDL			2	3	7	16	28
OLS	1	1		2	2	4	10
MMQR					2	6	8
AMG				1	1	2	4
DEA					1	2	3
GMM			1			2	3
CuP-FM/CuP-BC			1			2	3
Correlation	1	1	1				3
Logit					1	1	2
Ridge					1	1	2
DCCE					1	1	2
fsQCA		2					2
VAR					1	1	2
Others *	0	2	2	4	7	1	16

Notes: * Other models include: MSBN, 2SLS, SFA, SDM, AHP, IV, SDA, LMDI, DID, ECM, PSM, SEM, GWR, STIRPAT, threshold model and cointegration test.

3.4. Theories Used in Sample Research

According to the statistical results in Table 3, there are 44 different theories or hypotheses related to energy transition or economic development applied in the aforementioned literature. Among them, 28 theories or hypotheses were only used in one research, and a total of 28 research articles did not apply or explicitly specify any theoretical basis. Many of these studies attempted to validate completely opposing conclusions on entirely different theoretical or hypothetical grounds [2,71,72]. Therefore, it is essential to establish clear and common theoretical and hypothetical foundations.

Table 3. Theories applied in sample literature.

Theory	Pre-2015	2016–2019	2020	2021	2022	2023	Total
Environmental Kuznets Curve			4	3	7	10	24
growth hypothesis			1		2	3	6
feedback hypothesis			1	1	2	1	5
neutrality hypothesis			1		2	1	4
energy ladder theory		1			2	1	4
pollution haven hypothesis			1	1	2		4
conservation hypothesis			1		2		3
pollution halo hypothesis				1	2		3
demand and supply		2		1			3
Porter hypothesis theory					1	2	3
input-output (I-O) model		2					2
resource curse theory						2	2
Keynes theory			1			1	2
endogenous growth theory		1				1	2
No theories	3	2	2	2	10	9	28
Other theories *	2	7	2	4	5	8	28

Notes: * Other theories include: energy consumption, energy justice, energy stack theory, embodied energy, time–space telescoping, biophysical economics perspective, diversity hypothesis, sustainable theory, underlining theory, green competitiveness, coal–gas transition balance theory, systems theory, Schumpeter's structure economic theory, Cobb–Douglas production function, Bayesian probability theory, spatial correlation theory, wage theory, race to bottom theory, race to top theory, Heckscher–Ohlin model of international trade, theory of decoupling, transaction cost theory, endogenous production theory, energy-led ECD hypothesis, theory of development economics, new institutional economics theory, new growth theory, and vintage capital growth theory.

Undoubtedly, the most frequently used theoretical basis among all the sample literature is the Environmental Kuznets Curve (EKC), with many research articles attempting to verify this theory using various methods and data [73–75]. Following that is the growth hypothesis, applied in a total of six research articles, and then the feedback hypothesis, used in five research articles. The neutrality hypothesis, energy ladder hypothesis, and pollution haven hypothesis come next, each applied in four research articles. In the past, much of the literature focused on the relationship between pollution emissions and economic development, rather than exploring the economic development or transformation brought about by energy transition. Currently, the research on the relationship between energy transition and economic development is still in its relatively early stages, which explains the diverse range of theories focused on different aspects of energy, environment, and economic development in constructing the theoretical foundations of the research. Exploring the relationship between the two remains a crucial area for future research, where theoretical explanations, refinement, and clear applicability conditions for all empirical research conclusions need to be addressed.

3.4.1. Environmental Kuznets Curve

In our sample, 24 research articles applied the EKC theory, all which were published after the year 2020, showing an increasing trend from the initial four research articles to 10 research articles in 2023. The EKC describes the potential relationship between environmental pollution and economic development. It was originally proposed in [76], which primarily studied the relationship between economic growth and income changes. The application of this theory to the environmental dimension came later in research [77]. The fundamental premise of the EKC is that as the level of economic development increases, environmental pollution initially rises, but when a country or region reaches a certain income level, environmental pollution begins to decrease. In other words, environmental pollution exhibits an inverted U-shaped curve with respect to economic development, rising initially and then declining.

In the sample literature, scholars explored the relationships between carbon emissions, carbon footprints, energy consumption, energy transition, economic development, FDI, trade levels, and other indicators using the EKC hypothesis [75,78–81]. They conducted analyses from different perspectives, including causality, consequences, and the transformation's impact on development quality [30,60,68,82]. Previous research has considered the EKC as an essential component for understanding the environmental pollution problems associated with various levels of economic development, contributing to a broader understanding of the macroeconomy and environmental pollution.

Subsequent literature has continued to explore the existence of this theory or curve and question whether the initial assumption that the EKC exists due to the low priority given to environmental protection during early stages of economic development, leading to increased pollution through resource exploitation and industrialization, still holds true. As more and more countries abandon the "pollute first, clean up later" approach, it becomes essential to further investigate whether the economic development and energy transition discussion based on this theory is still valid.

3.4.2. Growth/Feedback/Neutrality/Conservation Hypothesis

The reason why these four hypotheses are analyzed together is that they are frequently presented and tested collectively [2,25,71,72]. They represent different conclusions on the same issue, and some conclusions are even completely opposite. In our sample, a total of nine research articles applied at least one of these theories, with the most common being the growth hypothesis [14,21,83] which was applied in six. The growth hypothesis suggests a unidirectional relationship between energy use and economic growth, indicating that an increase in energy use leads to economic growth [25]. Energy itself is considered a limiting factor for economic growth, and the transition, inadequate supply, and changes in energy types can have an impact on economic development. Consequently, as the economy moves towards less intensive energy production, it may potentially reduce the pace of economic development.

Among the four hypotheses mentioned above, the second-most applied is the feedback hypothesis [48,72,84], with a total of five research articles. This hypothesis posits a bidirectional causal relationship between energy use and economic development, suggesting that energy use and economic growth mutually influence and promote each other [25]. Thus, the hypothesis suggests that energy use and transition in a region can have a stimulating effect on its economic development, and this effect is complementary. Additionally, continuous energy transition, increasing the share of renewable energy or enhancing energy efficiency, is not expected to have negative impacts on economic development. Studies found that economic growth only affects clean energy transition in very high quantiles (0.60–0.95) [84]. On the other hand, research in [48] indicated that energy demand does not have a feedback effect on economic growth. Therefore, future research that clarifies the circumstances or ranges of conditions in which these feedback effects can exist will be crucial in supporting energy transition and economic development.

Ranking third is the neutrality hypothesis, with a total of four papers [71,72]. This hypothesis suggests that there is no causal relationship between energy use and economic development, implying that energy use has little or no impact on economic development and, vice versa, economic development has little influence on energy use [21]. It was found in [25] that the initial estimations support the neutrality hypothesis, and the results from comprehensive data on renewable energy also align with the neutrality hypothesis. If this hypothesis holds true, it implies that any country's energy transition would only need to consider its own natural resources and not concern itself with economic issues during the transition process. This aspect is worth further exploration and investigation.

Among the four hypotheses mentioned above, the conservation hypothesis ranks last with only three research articles utilizing it [25,71,72]. This hypothesis posits a unidirectional causal relationship between economic development and energy use, meaning that an increase in economic level will lead to higher energy consumption, and this influence is one-way only. This is the most direct and easily understandable relationship between the two, as all economic activities inevitably require resources and power, leading to increased energy consumption. This energy consumption may include the use of renewable energy sources [25].

3.4.3. Energy Ladder Theory

In all the sample literature of this study, the "Energy Ladder Theory" is also widely applied, with four research articles using it as the basis for their research design and analysis [18,85–87]. The energy ladder hypothesis emerged in the 1970s [88] and was formally proposed as a five rungs energy ladder model in [89]. Research on a global scale has found that high-income households prefer clean energy sources [85], with previous literature focusing on the clean energy preferences in economically advanced regions such as the United States and the European Union [87]. Ma et al. concentrated on China to examine how an increase in non-farm income promotes energy transition [18], while Ref. [86] developed an energy transition framework using data from Pakistan. According to this research, electricity is positioned at the top of the energy ladder, representing the highest form of energy use. The energy ladder theory suggests that as household wealth increases, households transition from non-clean energy to more efficient and cleaner energy sources [90,91]. This transformation is believed to follow a linear progression [92]. In their study, Ref. [18] examined the relationship between increasing non-farm income and decreasing coal expenditure in rural China to analyze rural energy transition. It was found in [87] that energy dependency and income significantly influence and alter local energy policies. It was found that Ref. [85] also supported the "energy ladder theory" in their research, emphasizing the importance of closely addressing the economic and energy poverty of vulnerable groups. However, Ref. [86] found certain flaws in existing energy ladder measurement models, suggesting that household income, as previously emphasized in other articles, is not the sole factor influencing household energy transition.

From the perspective of the application scope of the energy ladder theory, scholars tend to use it more at the individual or household level to study the relationship between economic conditions and energy transition. This differs from research conducted at the macro level. However, this distinction and dynamic viewpoint align with the previously mentioned quantile regression approach. In the context of diverse global or national economic structures, the energy ladder theory is likely to persist in the long term. This seemingly offers a categorization or differentiated approach for future research, which is crucial for a scientific understanding of the relationship between energy transition and economic development.

3.4.4. Pollution Haven/Halo Hypothesis

In the aforementioned literature, the pollution haven hypothesis (PHH) and the pollution halo hypothesis (PHlH) are frequently discussed together, appearing four and three times, respectively [2,31,93,94]. These hypotheses are linked to FDI and explore the impact of FDI on the host country's environmental pollution. The pollution haven hypothesis (PHH) suggests that developed countries, due to strict pollution regulations, relocate high-pollution industries to countries with stricter environmental restrictions through FDI. This can lead to an increase in the host country's economic development but also result in higher consumption of non-renewable energy, inhibiting energy transition [95,96]. On the other hand, the pollution halo hypothesis (PHlH) posits that such transfers, as a result of higher technology, can reduce pollution by introducing green technologies and promoting energy transition [94,97].

It was found in [2] that a negative correlation between FDI and energy consumption exists, which supports the PHH, but the FDI significantly promotes the consumption of renewable energy, thereby facilitating energy transition. However, Ref. [93] discovered that the relationship between FDI and energy transition is not linear, indicating that both the pollution haven and halo hypotheses exist. Another study by [94] also supports both hypotheses, showing that the impact of FDI on the environment varies across different sectors. Increasing FDI investment in the electricity sector can lead to sustainable development. It was found in [31] that energy transition can reduce the local pollution caused by FDI. The above analysis demonstrates that the pollution hypothesis may not be consistent when exploring different countries at various stages of development or even different sectors. Moreover, both economic development and energy transition are simultaneously influenced by FDI. This suggests that conducting quantitative empirical analysis solely focusing on economic development and energy transition could lead to the trap of omitted variables. Therefore, the research literature based on this hypothesis reminds us that future studies should be more comprehensive, incorporating as much background information as possible into consideration.

3.4.5. Other Theoretical Perspectives

The aforementioned theories are rarely applied. Among the 34 different theories applied in the literature, 28 theories were used in only one study each, such as the energy justice theory [64], energy stack theory [40], time-space telescoping [98], transaction cost theory [32], energy-led ECD hypothesis [14], and diversity hypothesis [46]. Additionally, the demand and supply theory, as a fundamental theory of economic development, was discussed in three studies. These studies suggest that future energy transition demands are not only related to economic development, but are also influenced by various factors such as electricity taxes and alternative product prices [65,99,100]. The resource curse theory was used in two research articles. This theory posits that resource-rich countries may inhibit economic growth and financial development [70,101].

3.5. Thematical Analysis

This section evaluates the sample studies of energy transition and economic development based on the themes discussed. This study summarizes 12 different research themes in this study, with the most extensively researched topic being the factors influencing energy, totaling 50 papers. Other themes range from 41 items to 3 items, indicating a wide scope of research on energy transition and economic development by scholars, with a relatively concentrated focus. Specific distribution of themes is shown in Figure 3.

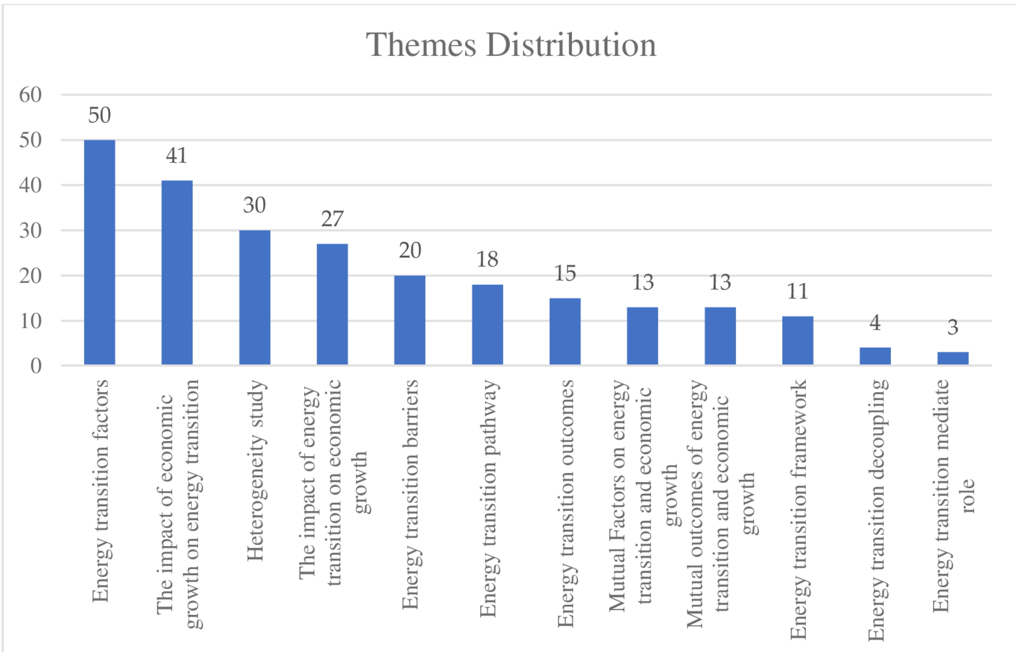

Figure 3. Themes distribution.

We found that these documents are focused on six distinct themes, including the influencing factors of energy transition, the impact of economic growth on energy transition, the influence of energy transition on economic growth, barriers to energy transition, and the pathways of energy transition and economic development. Table 4 presents the themes covered in all sampled literatures, and Table 5 shows the meaning of each symbol and label of Table 4.

Table 4. Summary table of all literature analyses.

Code	Authors	Method	Model	Theory	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	[71]	A	C	ABCDG		Y	Y				Y					
2	[102]	A	J	O						Y						
3	[73]	A	G	A	Y	Y										
4	[8]	B	N	N				Y						Y	Y	
5	[21]	A	BD	BD			Y									
6	[60]	A	A	A						Y	Y					
7	[103]	A	L	N						Y						
8	[64]	C	N	O	Y			Y								
9	[51]	B	O	N						Y	Y		Y			
10	[67]	A	B	N	Y	Y		Y		Y						
11	[69]	A	C	N	Y	Y							Y			
12	[61]	A	ABDO	O		Y			Y		Y					
13	[48]	A	A	C			Y								Y	
14	[104]	A	H	N				Y								
15	[31]	A	O	FH	Y		Y									Y
16	[94]	A	A	FH	Y					Y					Y	
17	[105]	B	N	N					Y					Y		
18	[84]	A	A	C	Y	Y		Y								
19	[47]	A	F	M	Y					Y			Y			Y
20	[50]	B	N	O				Y						Y		
21	[22]	A	A	O	Y	Y										
22	[106]	B	N	N		Y			Y	Y						
23	[75]	A	B	A				Y								
24	[100]	B	N	I	Y		Y		Y				Y			
25	[66]	C	N	O			Y	Y								
26	[68]	A	C	A	Y	Y										
27	[107]	A	L	O	Y			Y								
28	[10]	A	D	A	Y						Y					
29	[27]	A	A	N	Y	Y		Y								
30	[1]	A	A	N	Y	Y				Y			Y			
31	[41]	B	N	N			Y		Y							
32	[24]	A	O	O			Y			Y						
33	[108]	A	O	O										Y		
34	[11]	A	AO	N	Y	Y										
35	[29]	A	A	A						Y			Y			
36	[43]	B	N	O			Y		Y							
37	[19]	B	N	O			Y		Y							
38	[80]	A	C	A							Y		Y			
39	[30]	A	A	A						Y	Y					
40	[74]	A	A	A		Y										
41	[65]	C	N	I			Y	Y								
42	[23]	B	O	N			Y			Y						
43	[85]	A	O	E				Y								
44	[109]	A	J	O	Y											
45	[110]	A	A	A	Y	Y										
46	[83]	A	G	B									Y			
47	[111]	A	C	A									Y			
48	[99]	A	B	I	Y	Y			Y							
49	[112]	A	A	J	Y							Y				
50	[113]	A	M	N			Y		Y							

Table 4. *Cont.*

Code	Authors	Method	Model	Theory	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
51	[114]	A	C	A	Y	Y				Y						
52	[44]	B	N	N			Y		Y							
53	[12]	A	E	JO	Y	Y				Y						
54	[18]	A	O	E	Y	Y				Y						
55	[115]	A	BO	N			Y									
56	[98]	B	O	O	Y	Y				Y						
57	[2]	A	G	AFO	Y						Y	Y				Y
58	[6]	A	D	O	Y	Y						Y				
59	[116]	A	K	N		Y							Y			
60	[79]	A	B	A		Y					Y		Y			
61	[81]	A	A	A	Y	Y						Y				
62	[45]	A	B	A					Y		Y	Y				
63	[117]	A	O	N	Y	Y		Y						Y		
64	[39]	B	N	M					Y					Y		
65	[37]	A	O	N		Y										
66	[9]	A	A	A	Y					Y						
67	[118]	A	A	A	Y	Y		Y		Y	Y					
68	[28]	A	O	N	Y											
69	[25]	B	O	BCDG			Y			Y						
70	[78]	A	A	AO	Y		Y	Y								
71	[7]	A	O	A						Y	Y		Y			
72	[119]	B	N	O			Y		Y					Y		
73	[72]	A	A	BCDG	Y	Y	Y		Y							
74	[3]	B	N	K			Y		Y	Y				Y		
75	[70]	A	A	L								Y				
76	[63]	A	O	O		Y										
77	[120]	A	H	N						Y				Y		
78	[82]	A	F	A	Y	Y				Y						
79	[46]	A	H	O			Y									
80	[36]	A	K	N			Y					Y				
81	[121]	A	F	N	Y	Y						Y				
82	[122]	A	A	N	Y	Y						Y				
83	[123]	A	A	N	Y							Y				
84	[42]	B	N	N			Y		Y	Y	Y			Y		
85	[86]	A	I	E	Y	Y				Y				Y		
86	[124]	A	A	A		Y							Y			
87	[59]	A	O	O			Y			Y	Y					
88	[62]	A	A	AJO	Y		Y									
89	[14]	A	A	BO	Y	Y		Y								
90	[87]	A	I	E	Y	Y	Y									
91	[40]	B	N	O	Y	Y			Y	Y						
92	[93]	A	O	FH	Y						Y	Y				
93	[101]	A	C	L	Y	Y		Y								
94	[125]	A	A	O	Y											
95	[38]	A	A	O	Y	Y		Y								
96	[17]	B	O	O	Y					Y						
97	[49]	A	O	O	Y					Y		Y				
98	[33]	A	O	K					Y						Y	
99	[35]	A	BE	N	Y	Y		Y								
100	[32]	A	E	O			Y									
101	[15]	A	BC	O	Y	Y		Y								
102	[26]	A	A	N		Y						Y				
	Total				50	41	27	20	18	30	15	13	13	11	4	3

Table 5. Symbol and column label meaning.

Symbol Mean	Method	Model	Theory
A	Quanti	ARDL	EKC
B	Non-empirical	OLS	growth hypothesis
C	Descriptive	MMQR	feedback hypothesis
D		AMG	neutrality hypothesis
E		DEA	energy ladder theory
F		GMM	pollution haven hypothesis
G		CuP-FM/CuP-BC	conservation hypothesis
H		Correlation	pollution halo hypothesis
I		Logit	demand and supply
J		Ridge	Porter hypothesis theory
K		DCCE	input-output (I-O) model
L		fsQCA	resource curse theory
M		VAR	Keynes theory
N		None	None
O		Others	others

Column label mean	Themes
(1)	Energy transition factors
(2)	Impact of economic growth on energy transition
(3)	Impact of energy transition on economic growth
(4)	Energy transition barriers
(5)	Energy transition pathway
(6)	Heterogeneity study
(7)	Energy transition outcomes
(8)	Mutual Factors on energy transition and economic growth
(9)	Mutual outcomes of energy transition and economic growth
(10)	Energy transition framework
(11)	Energy transition decoupling
(12)	Energy transition mediate role

3.5.1. Energy Transition Factors

Under the requirements of the Kyoto Protocol and the Paris Agreement, an increasing number of countries have embarked on their own path towards energy transition. Regarding the influencing factors of energy transition, scholars have explored various aspects such as resource endowments, society, technology, taxation, income levels, international trade, domestic trade, and FDI [22,114]. They have found that energy transition is a systemic theme, and numerous factors can drive and enhance the pace of local energy transition. The main factors are shown in Table 6. Moreover, there are certain heterogeneities in the transformation elements across different regions or industries.

Table 6. Factors of energy transition.

No.	Factors	Opinion	Some Supporting Literatures
1	Technology	Technological increase the capacity to produce green energy	[22,62,93,107]
2	Financial support	Financial support is a crucial driving force for energy transition	[14,47,101,112]
3	Environmental governance	Environmental governance has a positive impact on energy transition	[27,38,84,114]
4	Human capital and population size	Human capital and population size positively improve energy transition	[11,12,14,125]
5	Taxation and rents	Taxation and rents accelerate the pace of energy transition	[11,35,68,100]
6	Foreign direct investment	Foreign direct investment influences energy transition but with different results for various situations	[10,31,81,94]
7	Information and communications technology	Information and communications technology accelerates energy transition	[2,22,121,123]
8	Educational levels	Higher levels of education lead to more energy transition	[40,86]

Table 6. *Cont.*

No.	Factors	Opinion	Some Supporting Literatures
9	Political stability	political stability has a positive contribution to energy transition	[15]
10	Exchange rates	Exchange rate has positive impacts on energy transition movement	[78]
11	Robust democracy	Robust democracy increases energy transition movement	[10]
12	Long-term strategies	Long-term strategies benefit to energy transition	[64]
13	Geopolitical risks	Geopolitical risks improve energy transition movement	[78]

Firstly, technology is the primary productive force, and thus, breakthroughs, utilization, and spillover of technology can effectively enhance energy efficiency and promote energy transition. Technological innovations increase the capacity to produce green energy to meet potential demand and expand the applicability of green energy [22,38,62,93,107,114,121]. It is found in [68] that environmental concerns and the development of renewable energy technologies have significantly reduced emissions and promoted energy transition. Technological innovation has a positive impact on the new energy industry, shifting the focus of transition from "dirty energy" to progressively cleaner alternatives [110]. Whether analyzed in the short or long term, technological innovation has a notable positive influence on energy transition [12,27,109]. It is not an exaggeration to say that technology is the foremost driving force behind breakthroughs in energy transition.

Financial support is a crucial driving force for energy transition [14,47,101]. It can be found in [47] that inclusive finance significantly promotes renewable energy transition, while Ref. [78] discovered that financial openness has a positive impact on Russia's energy transition. Also, Ref. [112] argued that green energy investments and the development of fundamental finance facilitate energy transition. It can be found in [123] that financial development not only directly affects but also amplifies the influence of environment-related ICT innovations and human development on energy transition. However, Ref. [72] found a significant negative effect of financial development on renewable energy consumption, indicating the need for sustainable financial mechanisms.

Environmental governance has a positive impact on energy transition [27,38,84,112]. In the long term, effective governance helps reduce carbon dioxide emissions and enables BRICS countries to both lower emissions directly and adjust the emission-reducing effects of FDI [10]. Environmental regulatory policies play a significant role in the development of renewable energy [12]. The positive effects of sound environmental governance will curb consumption-based carbon emissions in BRICS countries, improve energy use, and reduce energy consumption [114]. Among governance indicators, the rule of law and the quality of regulation have a positive influence on energy transition [15].

Human capital and population size have an impact on the growth of the green economy [12]. Human development significantly and positively promotes long-term energy transition in the G7 economies, thereby reducing greenhouse gas emissions [125]. Human capital can facilitate the development of renewable energy sources [14]. It was found in [11] that a positive correlation between population growth and China's energy transition exists.

The use of taxation and rents on certain energy or natural resources can effectively accelerate the pace of energy transition, as found by [100]. They discovered that levying taxes on coal, oil, and natural gas-based electricity generation is more conducive to energy transition and environmental sustainability. Similarly, Ref. [11] found a positive correlation between natural resources (total natural resource rents and natural gas rents) and Chinese energy transition. Increasing environment-related taxes significantly reduces total emissions, promotes energy transition, and fosters environmental sustainability [68]. However, Ref. [35] found that the impact of different rents varies. For instance, mineral and oil rents can facilitate energy transition, while forest and coal rents have the opposite effect. Some resource rents do not show a significant impact on renewable energy transition [99].

Research has found that FDI also influences a country's energy transition and ecological quality, but the impact varies among countries at different levels of economic development. It was discovered in [81] that FDI inflows increase the share of renewable energy generation and improve the environmental quality in Bangladesh. FDI has a strong emission-reducing effect [10], and for developing countries, it serves as a driver for green growth [31]. The improvement is particularly pronounced for the electricity and service sectors [94], however, Ref. [2] suggested that FDI reduces the overall use of renewable energy. Some studies have found that FDI does not have an emission-reducing effect [99], while Ref. [93] discovered a U-shaped relationship between FDI and natural gas consumption.

The trade of Information and Communications Technology (ICT) goods and services directly contributes to increased renewable energy consumption, accelerates energy transition, promotes the utilization of renewable energy, reduces energy intensity, and lowers carbon dioxide emissions [2]. The growth of ICT has a positive impact on investments in renewable energy technologies (RET) [121,123], whereas the decline in ICT has a negative effect on RET investments in both the short and long term [22].

Furthermore, scholars have found that political stability [15], exchange rates [78], robust democracy [10], education levels [40,86], geopolitical risks [78], and long-term strategies [64] also have certain impacts on energy transition. As discovered in [13], energy transition is influenced by a variety of factors, both positive and negative. Key factors include the required infrastructure, hardware, and software technologies for energy transition, while other factors such as investment, market conditions, environment, government and institutional roles, policy instruments, regulatory frameworks, and social acceptance are also identified as crucial elements of the transformation. Additionally, economic development significantly influences energy transition, which will be addressed separately as a key focus in the subsequent content.

3.5.2. Impact of Economic Growth on Energy Transition

The impact of economic development on energy transition is one of the core aspects of this study. Scholars have utilized data from global sources [82,98,116], South Asia [6], Africa [14,37,67], ASEAN [15], OPEC [118], OECD [71], BRICS [10,121], the European Union [103], China [18,40,87], Australia [122], Bangladesh [81], Pakistan [86], and Tunisia [72] in order to perform a comprehensive stratified analysis. This analysis has led to two completely different conclusions. The majority of studies suggest that economic development promotes the use of renewable energy and effectively improves energy transition, although there might be feedback pathways [71]. On the other hand, some studies argue that economic development hinders energy transition and increases pollution emissions [38,79]. The main points of view are presented in Table 7.

Table 7. Research conclusions about economic growth impact to energy transition.

Research View	Opinion	Some Supporting Literatures
Macro-perspective	Economic development promoting pace of energy transition	[14,15,22,27,35,73,121]
Micro-perspective	Income is a significant factor influencing household energy transition	[40,67,86,87,98,116,118]
Various view	Dependence on economic development and additional governance costs hinder energy transition	[38,79]

Firstly, from a macro-perspective, the increase in real GDP leads to an increase in investments in RET, thus promoting the pace of energy transition [14,22]. It was found in [6] that higher levels of economic growth and carbon dioxide emissions promote the use of renewable energy in South Asia. Also, Ref. [79] suggested that economic growth is the solution to the environmental issues faced by Bangladesh, while Ref. [99] discovered that economic development expands the scale of energy transition but weakens the share of some clean energy sources. Renewable energy consumption appears to be stimulated by economic growth [72,110]. As revealed by Ref. [15], economic growth significantly promotes energy transition in ASEAN countries, consistent with the findings in China [11,63]. In contrast, Ref. [73] argued that economic growth, once reaching a certain level, will restrain carbon dioxide emissions and become an important driving factor for energy transition in an economy [35]. Therefore, economic growth not only has a certain emission-reducing effect but also increases the level of renewable energy usage. Increasing the GDP of BRICS countries can boost the demand for energy transition and deployment of renewable energy [27,121].

Secondly, from a micro-perspective, income is a significant factor influencing household energy transition [40,86,87]. As found in [118], a unidirectional causal relationship exists between income level and renewable energy consumption. Although different levels of economic development may affect the pace of energy transition differently, economic growth indeed improves energy transition [98] and increases the electrification rate [116]. However, Ref. [67] concluded that key factors contributing to regional disparities during the energy transition process are the level of urbanization, resource scope, and economic growth, resulting in variations among different regions. In the context of rural areas' energy transition, Ref. [18] discovered that non-agricultural income increases rural households' expenditure on renewable energy consumption while reducing expenditure on coal. Additionally, in economically developed areas, the transformative effect of non-agricultural income on energy transition is more pronounced. Economic growth only affects clean energy transition in a very high percentile range (0.60–0.95) [84].

It is contended in [71] that the relationship between economic growth and ecological environment is no longer unidirectional. Instead, there exists a feedback causal relationship between the two. Economic growth can lead to environmental degradation [61,69,106,122] as it increases pollution, distorts the environment, and significantly contributes to short-term and long-term environmental damage [101,114,124]. Dependence on economic development and additional governance costs might hinder energy transition [38].

3.5.3. Impact of Energy Transition on Economic Growth

An essential objective of this study is to examine the impact of energy transition on economic development. Overall, it yields three different conclusions: positive impact [115], negative impact [65], and a bidirectional causal relationship [71], which fit the previously mentioned growth hypothesis and feedback hypothesis. Even the findings from different countries or different time periods are inconsistent. For instance, Ref. [25] found a unidirectional causal relationship between energy transition and economic growth for Spain and other EU countries, but for Spain, there exists a bidirectional relationship. On the other hand, Ref. [21] unveiled that in the long term, energy transition positively affects economic growth, however, in the short term, energy transition has a negative impact on economic growth. The main conclusions are displayed in Table 8.

Table 8. Research conclusions about energy transition impact to economic growth.

Conclusion	Opinion	Some Supporting Literatures
Positive	Energy transition has a benign net impact on economic development	[3,32,42,62,66,87,100]
Negative	Energy transition may hinder economic development	[19,36,43,46,119]
Bidirectional	Different energy transition paths, countries, or time periods lead to different results of economic development	[21,25,41,44,59]

Most scholars believe that energy transition itself seems to have a benign net impact on the macroeconomic fundamentals [66] as it fosters the adoption of economic means and solutions [87]. A macroeconomic model that considers regional, economic, and sectoral characteristics was used in [3], which found that energy transition provides opportunities for economic enhancement. Green economic growth is stimulated through the use of green energy [62]. During the transition from traditional energy to clean energy, taxing certain forms of energy generation can improve the economic environment [100]. Low-carbon energy transition was measured in [42], which can promote economic growth while mitigating the impact of climate change. As determined in [115], households that underwent a clean energy transition experienced an average increase of 12.2% in household economic development. China's digital energy transition has improved economic sustainability [32], facilitated green transformation in economic development [24], and led to economic growth in China that is balanced [113].

However, certain scholars reach divergent conclusions, proposing that energy transition could impede economic development to a certain degree, with Ref. [19] designing an endogenous economic growth model constrained by real-world limitations which found that the transition to renewable energy could potentially have a negative impact on economic growth (entering a phase of decline after reaching its peak). The increase in the proportion of renewable energy may incur certain economic costs, which could be detrimental to regional economic growth [36]. The capital-intensive investment in energy transition can lead to negative effects such as economic stagnation and recession [43]. Economic indicators show improvement as energy intensity decreases [46]. The Energy Extended Neoclassical Growth Model (EENGM) was developed by [119] which found that underperforming energy sectors could limit GDP growth.

Meanwhile, Ref. [41] developed three scenarios and found that different paths have different positive impacts on the Chinese economy, thus achieving varying degrees of dual dividends. However, Ref. [44] established three scenarios and found that the impact of different energy transition paths on the macroeconomic performance of China is inconsistent. Energy transition has a positive contribution to the decoupling process in high-income economies, while it does not have a positive contribution to the decoupling process in middle- to high-income and middle- to low-income economies. High-income groups have better energy utilization efficiency, which offsets the negative impact of the economic scale during energy transition [59].

Some studies also support the feedback hypothesis, suggesting a feedback causal relationship between economic growth and ecological footprint [71]. Employing a nonlinear Granger causality test, Ref. [72] revealed a bidirectional causal relationship between renewable energy and economic growth. On the other hand, Ref. [48] found that the demand for energy transition does not generate a feedback effect on economic growth.

3.5.4. Various Energy Transition Barriers

Regarding the barriers to energy transition, some aspects have already been covered in the factors influencing energy transition. In this study, we primarily focus on the specific factors that scholars have explicitly identified as hindrances to energy transition in past research. Numerous past studies have focused on barriers in the process of energy transition such as scarcity of environmental resources [35], ineffective governance [64], and capital challenges [66]. Due to differences in research subjects, periods, and methodologies, some factors may be perceived as promoting energy transition in other studies [78].

Among all factors, the most widely recognized barrier is the scarcity of environmental resources, commonly believed to impede energy transition at the national or regional level [35,67,84,104]. Employing the legit quantile autoregressive distributed lag (QARDL) model, Ref. [84] analyzed data on China's energy transition between the years 1999–2019. The findings reveal that environmental resources exert a negative influence on energy transition across all quantiles. Secondly, in the long term, ineffective government, mismanagement, lack of transparency, and policy corruption disrupt energy transition [14,15,64]. As introduced by [15], the methods of movement quantile regression (MMQR) is used to investigate the role of governance indicators in energy transition within ASEAN during the period of 2000–2020. The study revealed that ineffective governance has a negative impact on energy transition at medium and higher quantiles. Thirdly, since energy transition requires comprehensive and long-term efforts, the inadequacy of long-term capital and financing instruments or channels is also a significant hindrance to the transition [50,66,101]. A macroeconomic model and an energy model was developed by [50], revealing that in the long term, insufficient capital in the energy sector will slow down the pace of energy transition, thus impeding the global progress towards a complete energy transition. Fourthly, as mentioned earlier, some scholars have found that economic development can obstruct energy transition [38,65,78].

According to research, there are many other factors that may limit the pace of energy transition. Elements such as path dependence, uneven development, and material deprivation can all impede energy transition [104]. Moreover, factors deeply rooted in local cultural norms and values such as caste, trust, social capital, information flow, and cluster social positioning, act as barriers to energy transition. These factors are difficult to change [107]. Population growth, inflation rate [78], institutional and policy choices [75], policy uncertainty [38], inadequate social pensions [85], urbanization [118], and trade openness [27] are all additional potential obstacles to energy transition.

Some scholars have explored the important factors that could promote, hinder, or shape energy transition through the establishment of different models, including technological innovation, economic growth, social compliance, and regulatory and institutional frameworks [117]. Additionally, Ref. [8] examined energy security transformation by constructing a 4-As framework, which considers energy availability, technological applicability, environmental and social acceptability, and energy affordability. By summarizing the findings of literatures, Ref. [13] found that in many places around the world, obstacles to energy transition have been identified. A lack of appropriate coordination in policies and inconsistent regulations are also key factors hindering energy transition. Although the above analysis does not lead to a unanimous conclusion, the research on these frameworks, models, and factors provides insights for us to further clarify the obstacles to energy transition in different regions, reduce transition resistance, and sustainably improve both environmental and economic development.

3.5.5. Diverse Energy Transition Pathway

Different countries or regions have distinct energy transition paths with unique characteristics. Scholars often use scenario assumptions or factor analysis methods to explore these paths [44,45]. One approach involves setting different scenarios for various sectors based on the future energy transition goals, thereby identifying the transition pathways [41,105]. The other approach is to consider the influencing factors and barriers to transition, seeking benefits and avoiding risks, promoting favorable factors, and reducing transition obstacles [72,100].

For the first type of scenario-based research, the most commonly used method is the general equilibrium model [41,44,105], which simulates and estimates the impacts of different energy transition pathways on China's macroeconomy and the transition pathways for China's western region until 2050. The Medea-Europe model proposed by [39] found that only the post-growth scenario can achieve the EU's 2050 climate targets and maintain employment levels. The Asia-Pacific Integrated Model (AIM/Enduse) was utilized by [40] to estimate the energy transition pathway for the building sector, while Ref. [106] combined Gray forecasting with NAR neural networks to identify the optimal transition pathways for energy transition in China and the United States. A macroeconomic model incorporating economic, regional, and sectoral characteristics was used by [3] to propose different sectoral energy transition pathways and efficiencies for Germany until 2030, while Ref. [42] presented three modeling case studies suggesting the need for financial support and technology transfer for future low-carbon economic development. It was found by [19] that carbon pricing is crucial for achieving energy transition and sustainable economic development. Through analyzing past literature, Ref. [13] proposed that energy transition should be advanced through international cooperation, setting tangible targets, bottom-up participation, policy reforms, and improving the external environment.

Other scholars have analyzed the impact factors of energy transition and proposed various approaches. They suggest improving financial levels [72], increasing oil prices [99], implementing green trade globalization strategies [45], establishing a diversified energy structure based on decarbonization [33], taxing coal, oil, and gas-based electricity generation [100], promoting technological and structural changes [61], and developing transformation models from institutional, economic, and technological perspectives [113].

3.5.6. Other Topics of the Sample Literatures

As shown in Table 4 and Figure 3, along with the five main themes mentioned above, the literature included in this study covers several other common topics. Firstly, there is a plethora of research articles focusing on regional, sectoral, and period effect differences [3,67,98]. Due to significant variations in social, cultural, technological, and economic development backgrounds among different economies, scholars have extensively explored this issue. The energy transition process of the United States was compared by [98] with several developing economies, which found that there were three differences between trends.

Secondly, there are some research articles discussing the outcomes of energy transition, mainly emphasizing the explanations and measurements of carbon emission reductions resulting from the transition [2,60]. In [60], the world was divided into four income-classified countries and found that energy transition had significant and positive impacts on the environment of most income-classified economies. Additionally, globalization only played a significant role in middle- to low-income economies.

Next, there is another topic about the common reasons behind energy transition and economic development [2,93], as well as the mutual impacts between economic development and energy transition, exploring the shared influencing factors and development outcomes of both [7,51]. In [7], data from 26 EU countries spanning from 1990 to 2015 was utilized to apply a fixed-effects dynamic spatial Durbin error model to analyze the impact of economic growth and energy transition on carbon dioxide emissions.

Furthermore, other themes such as the analysis frameworks of energy transition [105,120], energy transition decoupling from economic development [8,33], and the intermediary role of energy transition are also explored [2,47]. An energy model was proposed [105] to assess different energy development scenarios for western China and put forward various energy transition frameworks, while Ref. [33] focused on Beijing and discovered that from 2007 to 2015, there was a decoupling of economic development and energy consumption in Beijing, with significant progress made in the coal phase-out process. The mediating role of economic growth and energy efficiency was analyzed [47] based on a balanced panel dataset of 73 countries during the period from 2004 to 2017. These varied themes contribute to a comprehensive understanding of the different aspects of energy transition and their connections with economic development.

It can be observed that scholars have extensively explored the relationship between energy transition and economic development from various aspects, including influencing factors, obstacles, interconnections, common drivers and outcomes, transition paths, and model frameworks. These research efforts have yielded fruitful results while also acknowledging heterogeneity and identifying applicable scopes and research limitations. The findings of these studies are not always consistent and may even contradict each other, highlighting the complexity of the subject. However, these divergent conclusions provide a clear direction and ample space for further investigation in terms of data, methodologies, research subjects, and applicable ranges.

4. Results and Discussion

Energy transition has reached a critical juncture, and the academic community is increasingly concerned about how to maintain economic growth during this process. This is not only a theoretical issue but also a practical one. In this study, we adhere to a systematic approach and comprehensively review all research on energy transition and economic growth.

4.1. Research Themes and Conclusions

Existing literature samples have proposed various relationships between energy transition and economic development, including unidirectional relationships [21] and mutual causality [87]. The primary focus of this study is to investigate the impact of economic development on energy transition, encompassing both promoting and inhibiting effects. Most studies indicate that economic development fosters the adoption of renewable energy sources and enhances energy transition, although potential feedback mechanisms exist [71]. Conversely, certain studies posit that economic development obstructs energy transition and leads to heightened pollution emissions [38,79]. It was found in [15] that economic growth significantly promotes energy transition in ASEAN countries, while [35] discovered that economic growth facilitates energy transition. However, the role of different resources and funds in energy transition varies. On the other hand, Ref. [84] unveiled the fact that economic growth only affects clean energy transition at very high quantiles, and industrialization has no impact on energy transition across all quantiles. This indicates that economic growth does bring about changes in local energy transition, which are influenced by factors such as income levels, education levels, and resource availability [40].

Furthermore, energy transition also impacts economic development, with effects varying in the short and long term, and across different ranges, potentially having positive, negative, and bidirectional causal relationships [65,71,115]. Scholars have attributed the divergent research conclusions to differences in research subjects, such as disparities between developing and developed regions [7,30,32], different research levels [1,38], limited number of studied countries [11,31], and insufficient research data [108]. Therefore, it is essential to broaden the scope of research [7], expand the study subjects [14], conduct grouping or classification studies [2], extend data periods [68], and perform heterogeneous analyses [31].

4.2. Factors and Variables

Research has found that driving factors and barriers for energy transition include economic development [38], rent and taxes [35], government [27], and policies [75]. The relationship between energy transition and economic development exhibits various outcomes such as mutual causality [71,72], unidirectional promotion [66], and unidirectional inhibition [78], among others. The academic community has not reached a consensus, and this inconsistency may be attributed to the exclusion of other variables [49]. Potential variables or factors that can be considered based on different literature include interest rates [78,82], institutional quality [111,121,122], subsidies [72], aging population [51], patents [110], fiscal decentralization [112], digitization [112], and other energy sources [21,45,99].

The multitude of influencing factors underscores that global energy transition is a systemic issue [114]. Many factors can drive and expedite local energy transition, and for different countries and regions, a comprehensive consideration of their own resource endowment [5,52], level of economic development [14], technological proficiency [22], financial support capacity [47], and environmental governance capability [84], is necessary to advance energy transition. Only through such considerations can a more suitable path for energy transition be chosen.

4.3. Research Methodology and Theories

Through the analysis of research methods, it can be observed that the current approach has evolved from simple, linear, single-year studies to more complex, non-linear, multi-year, and multi-case research methodologies [31]. It is suggested that, in order to identify more appropriate proxy variables [108], employing various methods such as content analysis, interviews, or questionnaire surveys is necessary to collect data [79,102,108]. Some research used more complex methods such as quantile ARDL technique for regression and causality analysis [30,45], CS-ARDL [26], employing the Tapio decoupling model combined with LMDI decomposition method [59], and utilizing more robust logarithmic cost functions [102] to clarify the effects at different quantile positions (rather than average effects) to discuss the effect of different groups or scenario.

Our research findings indicate that current energy, environmental, and economic theories have been widely applied in exploring the relationship between energy transition and economic development [76]. Many of these theories can potentially guide future research and help address the complexities of this relationship. As the EKC theory has been the most extensively used in the sample literature and provides a solid theoretical foundation for studying the link between energy transition and economic development, it is important to note that all the theories applied in different cultural contexts, individual characteristics, and even different sectors may yield varied results [84]. Therefore, refining the analysis granularity and conducting quantile or group studies based on certain indicators should be considered for deep research.

5. Conclusions and Future Works

With increasing attention to regional energy transition issues in the literature, this study systematically introduces an in-depth assessment of the relationship between energy transition and regional economic development, focusing on exploring various methods used in previous research. While the theme of energy transition has gained recognition in most countries and regions, the specific transition paths and influencing factors have not reached a consensus in the research. We conducted a comprehensive search in the Scopus database using seven keywords related to energy transition and economic development, yielding 4133 results. Through language, subject, literature type, and screening, we narrowed it down to 102 articles. The academic community's interest in this issue has been growing, and this paper provides a comprehensive analysis and evaluation of the sample literature in terms of annual trends, regional distribution, research methods, models used, theoretical frameworks, and prior research achievements. Furthermore, we discuss the research themes, conclusion, factors, methodology, and theories.

The research results of this study have seen a significant increase in studies on this topic in the past three years. Nearly half of the research focuses on cross-regional countries or economic entities and adopts various research methods, including quantitative, qualitative, and descriptive approaches. Over the previous three years, the most used research method is the ARDL approach, and the most applied theory is the Environmental Kuznets Curve hypothesis. These findings reveal that the sample literature primarily concentrates on energy transition factors, including technology, financial support, environmental governance, human capital, taxation, rents, FDI, among others. Another key area of research is the relationship between economic growth and energy transition, which encompasses unidirectional promotion, unidirectional inhibition, bidirectional causality, and no effect, among others. Additionally, other research themes in the literature include energy transition barriers, energy transition pathways, research heterogeneity, and energy transition outcomes.

The contributions of this study are as follows. Firstly, through a comprehensive review of existing research, it systematically analyzes the influencing factors of energy transition and the correlation between economic development and energy transition. Our research provides a crucial comprehensive review for the current study on energy transition and economic development, identifying the shortcomings in past literature and suggesting avenues for future research improvements such as focusing on research subjects, data, other influencing variables, and enhancing research methodologies. Secondly, the uniqueness of this study lies in its comprehensive review of background theories and core relationships, addressing the gaps in existing research, and conducting a meticulous evaluation of past studies to enrich the knowledge base, thus providing valuable analytical results and future research recommendations. Thirdly, this study offers a broad set of discoveries on energy transition that can assist policymakers and researchers in determining their coordinated paths for energy transition and economic development based on regional resource endowments, cultural traditions, and industrial structural characteristics.

Future research can focus on aspects such as research subjects and data, influencing factors and variables, and research methods. Therefore, in future research, it is suggested that the research scope be expanded based on current research conclusions [1,7,9,78,111]. For instance, as mentioned by [112], future studies may compare results from G20, BRICS, OECD, or other regions and countries. Alternatively, the research could be extended to include developed economies such as the OECD, N11, G7, the Middle East, and North Africa [14]. Another approach involves further subdividing the existing research subjects through grouping and classification, aiming to explore the reasons for variations in research conclusions among different subjects [2,81,94,99,106]. For example, as proposed by [30], heterogeneity analysis could be conducted for sub-Saharan Africa, Latin America, the Caribbean, South Asia, East Asia, and the Pacific. It was also suggested in [38] that performing regional heterogeneity analyses for China could be of great value. Grouping countries for analysis could yield interesting insights [31]. A third approach involves increasing data availability and extending the research data period [68,71,80], leading to more robust results. Future work can also go beyond direct factors and consider relevant mediating or moderating variables [2,31,47] to explain the complex relationship between energy transition and economic development better.

Author Contributions: Conceptualization, U.H.A.K., Y.W. and X.T.; methodology, X.T. and S.F.A.K.; software, X.T.; validation, X.T. and U.H.A.K.; formal analysis, X.T. and S.F.A.K.; investigation, X.T. and U.H.A.K.; resources, X.T. and Y.W.; data curation, X.T., U.H.A.K. and S.F.A.K.; writing—original draft preparation, X.T and S.F.A.K.; writing—review and editing, X.T. and U.H.A.K.; visualization, X.T.; supervision, U.H.A.K. and S.F.A.K.; project administration, X.T.; funding acquisition, Y.W. and X.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Open Fund Project of Science and Technology Finance Key Laboratory of Hebei Province (STFCIC202213; STFCIC202102); S&T Program of Hebei (22567630H); Hebei Social Science Fund (HB22YJ026); Baoding Science and Technology Bureau science and Technology Plan Soft Science Project (2340ZZ013); and the Hebei Social Sciences Development Project (20230202051).

Data Availability Statement: Data in support of the findings within this study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

ARDL	Autoregressive Distributed Lag Models
OLS	Ordinary Least Square
MMQR	Method of Moments Quantile Regression
AMG	Augmented Mean Group
DEA	Data Envelopment Analysis
GMM	Generalized Method of Moments
CuP-FM	Continuously updated and Fully Modified
CuP-BC	Continuously updated and Bias-Corrected
DCCE	Dynamic Common-Correlated Effects
fsQCA	Focused Stepwise Quantitative Case Analysis
VAR	Vector autoregressive model
MSBN	Microsoft Bayesian Networks
2SLS	Two Stage Least Square
SFA	Stochastic Frontier Analysis
SDM	Spatial Dubin Model
AHP	Analytic Hierarchy Process
IV	Instrumental Variable
SDA	Structural Decomposition Analysis
LMDI	Log Mean Divisia Index
DID	Difference-In-Difference
ECM	Error Correction Model
PSM	Propensity Score Matching
SEM	Structural Equation Model
GWR	Geographically Weighted Regression
STIRPAT	Stochastic Impacts by Regression on Population, Affluence, and Technology
EKC	Environmental Kuznets Curve

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