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Review

Exploring the Impact of Economic Growth on the Environment: An Overview of Trends and Developments

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Abstract: In our modern world, energy keeps the global economy running, and economic growth concerns are profoundly interrelated with environmental quality issues. Interestingly, scientists engage with empirical research to identify the impacts and causalities at the interface of economic activities, energy supply, and demand. The importance of the present study lies in a discussion of all contemporary research efforts bridging two strands of empirical literature in environmental economics: developments in energy growth nexus discussion and the environmental Kuznets curve. Furthermore, it highlights the inclusion of untested explanatory variables and the impacts on environmental degradation levels. In the context of the EKC hypothesis, the most popular indicators are greenhouse gas emissions (GHGs) and carbon dioxide emissions in conceptualizing environmental degradation. A review of relevant empirical studies disclosed additional research opportunities that can consider currently untested and less visible proxies of economic growth. For both strands in the literature, results differ based on the group of countries investigated, the econometric models adopted, the format of data, e.g., time series or panel analyses, the time frames due to data availability, and the proxies used to conceptualize energy, environmental degradation, and economic growth. Practical implications indicate that environmental degradation can be avoided or significantly limited within sustainable economic growth to reduce carbon dioxide emissions and increase the use of renewables in the energy mix. Furthermore, one particular implication is the concept of energy efficiency to reduce relevant demand to produce the same outcome or task.

Keywords: energy growth nexus; environmental Kuznets curve; economy; emissions

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1. Introduction

In our modern reality, competition within the natural environment stresses the importance of continuously developing economic activities in an environmentally friendly mode without losing much from business targets and pursuits. An issue highlighted in the work of Halkos [1,2], who investigated the relationship between environmental quality and the economy in terms of the EKC hypothesis, is defining a certain point beyond which growth does not impact environmental quality levels. The unwise use of resources or, even worse, the inefficiency in allocating them leads to dysfunctions and discrepancies that affect natural systems. These issues are highly correlated with growth, environmental concerns, and energy to achieve desired rates of economic performance. It is crucial to achieve sustainable economic growth based on the wise use of natural resources to continue to receive environmental benefits from ecosystem goods and services that nature generously provides to us.

Although many scientists have implemented research efforts, this issue is still being researched based on multidisciplinary research efforts. Such research efforts are undertaken to define how environmental and energy-related aspects (e.g., environmental degradation, energy consumption patterns) contribute to retaining the global economy while being run in a sustainable manner. For instance, it is widely known that energy management is a crucial aspect and an integrated part of policies enacted to alleviate poverty, battle the phenomena of social exclusions, and enhance inclusive economies regarding development and growth [3]. From this perspective, it is essential to perceive the connection between energy and, most correctly put, renewable energy consumption with growth rates to enrich the relevant literature on energy economics and to form a sustainable energy future [4]. Central to these endeavors remain the cause-and-effect relationships and how environmental quality or energy consumption affects the course of growth. While research findings for a wide range of factors have enhanced growth, the results could be more robust when the causal nexus between growth environment aspects are researched [5].

The integrative review methodology provides a gathering and synthesis of knowledge, scientific information, and the applicability of the results of cutting-edge research studies [6]. To this effort, the linkages between growth (e.g., GDP) and environmental variables (e.g., carbon emissions) have been reviewed in relation to promoting the idea of advanced environmental performance and quality within the economic system. Consequently, the purpose of the present integrative review effort is to investigate contemporary research efforts in the field of EKC hypothesis and energy growth nexus discussion and to understand comprehensively how these contemporary topics evolved from different points of view. The scientific argument behind such an attempt is that linkages between energy, the environment, and the economy dominate the relevant literature to form management plans based on natural resource and environmental economics. Supportively, the scientific domains of these disciplines have emerged over decades as a substantial specialization of economic theory and application [7].

No one would deny the importance of living and acting in a safe and healthy environment in which the economy, humans' well-being, and the natural environment interact to make a system, the performance of which regulates our living status and economic viability to a great extent. Many efforts have been made to effectively handle, manage, restore, alleviate, and mitigate natural damages and negative externalities, and interdisciplinary committees pay attention to putting into practice environmental management and marketing plans. In order to drop the global warming potential of the products under study, it is important to identify their core aspects and deploy the future projections of the relevant demand and energy and material supplies concerning their entire life cycle [8]. The energy generated from carbon fuels releases significant amounts of greenhouse gases that envelop the whole planet and consequently trap the sun's heat [9]. In the same framework, the environment, as a complex system in which natural settings and human intervention interrelate, allows the bringing together of a wide range of interested parties that seek benefits and gains through resource exploitation and the execution of relevant business plans. Continuous resource use and unstructured and unwise policies supported by conventional cultivation methods have made natural ecosystems vulnerable and have seriously threatened their resilience and integrity. Correspondingly, adverse effects have been experienced regarding cultivation costs and profitable production. Over time, such behavior has increasingly raised concerns about the challenges related to resource quality, availability, consumption, and market potential, not to mention population growth and demand projections.

By acknowledging the challenge of managing the environment sustainably, this study comprehensively reviews a series of selected published articles that discuss, in a thorough manner, the relationship between environmental quality, energy consumption, and economic growth. To this end, two main strands in the relevant literature dominate the research: the energy growth nexus discussion and the EKC hypothesis. A review of relevant empirical studies has disclosed additional research opportunities that can consider currently untested and less viable proxies of economic growth. For instance, given the significance of tourism in the global economic system, researchers can test the EKC in the context of high-impact, dynamic, and profitable market segments with noticeable predictive power.

The structure of the paper is as follows. The methodology section presents the theoretical background of the review process followed in this study. The following section includes the data extraction process. Next, the two following sections concentrate on the results concerning the energy growth nexus discussion and the testing of the EKC hypothesis. The Discussion and Implications section focuses on the gathered information and presents the implications practically. Finally, the last section concludes the results.

2. Methodology

All scientific domains need literature reviews established through a methodology that is precise and well addressed and reported [10]. Literature reviews summarize individual research studies and articles to integrate current knowledge concerning a scientific topic [11]. In the present study, an integrative review is attempted to shed light on the two main strands in the literature concerning the EKC hypothesis and the energy growth nexus discussion. Such an attempt lies in the approaches used to explore how researchers conceptualized the key dimensions of sustainable development, namely energy, environment, and economy. This integrative approach constitutes a helpful way of critically reviewing hypotheses or research questions that dominate a wide range of existing research attempts. Integrative reviews feature largely in the literature as they summarize research efforts comprehensively (e.g., empirical or theoretical), and they facilitate our understanding of particular key review points for the subject under question. Integrative reviews enable researchers to go beyond analyzing and synthesizing primary research findings and offer new inputs and gathered knowledge concerning a certain topic [6]. In the same manner, integrative reviews allow the researcher to exceed the process of analyzing and synthesizing the findings of primary research studies [12]. Furthermore, integrative reviews value both quantitative and qualitative research, simultaneously broadening the range of the research designs and empirical findings from the reviewed literature. Thus, they present a complete and precise picture of the research work available concerning a theoretical or conceptual framework or empirical research for a particular scientific field or domain. Their contribution is in gathering scientific information and synthesizing evidence relevant to a clearly defined problem or hypothesis [6]. The core elements of an integrative review process are the definition of the concepts under research, a review of theories of interest, the identification of gaps in the literature, and an analysis of methodological issues. Although not experimental in nature, integrative reviews can be characterized as research efforts since they demand a rigorous exploration of all types of research under a specific question and require a comprehensive synthesis of scientific evidence. Integrative literature reviews are planned to address mature topics or new, emerging topics. As mentioned above, this study intends to elaborate on the mature topics and synthesize relevant scientific evidence concerning the EKC hypothesis and the energy growth nexus discussion. Both issues have been explored extensively in the literature, and a need to thoroughly present the findings received is of high importance to perceive how these issues have evolved so far. As a scientific topic matures and the size of its literature increases, a corresponding growth and development in the knowledge base of the topic exists [13]. By adopting the integrative review approach, a researcher can investigate the published evidence concerning a specific phenomenon, thus recognizing potential research gaps that should be addressed as a function of subsequent research. The integrative process summarizes multiple types of evidence with numerous methodologies while it delivers a wider, more inclusive scientific view of the topic [14]. In the present work, an integrative literature review was selected. As indicated by [6], the systemic literature review is used to obtain evidence-based answers [15], based on investigating a well-determined research question while following a clear, pre-defined, reproducible, comprehensive, and systematic method to identify, choose, critically evaluate, synthesize, and analyze all important primary studies, in view of limiting potential bias [16]. However, the integrative process exceeds the potential to comprehensively review the literature since it surpasses the typical process of synthesizing and analyzing the existing research findings [12]. Additionally, it allows for the incorporation and integration of quantitative and qualitative data or additional options (e.g., encompassing scientific points of view, policy documents, and discussion papers), therefore offering a deeper understanding directly related to the specific interest of the review (e.g., the phenomenon under investigation) [14,17,18]. Moreover, the integrative approach is different from other forms of review, for instance, the realist review or the realist synthesis. The realist review mainly concentrates on perceiving the underlying forces behind the effectiveness or success of a research topic while the integrative literature review has a wider research scope [19], summarizing multiple pieces of evidence proved by various methodologies [14]. Consequently, it provides opportunities for a more inclusive and thorough scientific view [12], and it increases the potential and capability for generating a theory and organizing constructs for the topic under investigation [20,21].

3. Data

The integrative review was created based on dependable and accredited studies by the international scientific community, namely studies that appeared in Scopus and Science Direct. The present study's authors first reviewed the abstracts and the purposes of the retrieved research studies. All studies that met our inclusion criteria were then listed for further elaboration. It should be noted that the inclusion criteria for further elaboration were as follows: a well-articulated and clearly justified contribution to the relevant literature (e.g., research gap); a blind peer-reviewed published paper versus unpublished studies; the year of publication (e.g., publications after the year 2000); the contemporary research methodologies followed robust and reliable econometric models; and language restrictions. One particular criterion was the novelty of the variables of interest used to test the EKC hypothesis. For instance, we included studies that adopted dependent variables other than the traditional Gross Domestic Product growth variable and explanatory variables such as tourism market segments. The same way of thinking was followed in the case of the energy growth nexus. We selected papers that included untested or less visible explanatory variables (e.g., nuclear energy) and consequently tested their predictive power on the growth variables using regression equations. Similarly, we included studies that tested unobserved growth-dependent variables in the model specifications, such as the Index of Sustainable Economic Welfare (ISEW). For both cases, namely the EKC and the energy growth nexus discussion, our primary intention was to avoid generalizations and to simply gather and present past research efforts. Our data extraction purpose was to concentrate and thoroughly analyze studies that have added to the relevant literature and have thoroughly progressed relevant research efforts on these two specific research fields over the recent years. After completing the above data tasks, we classified the studies based on the scientific topic of interest, for instance, studies that discussed the EKC and research related to the energy growth nexus discussion. Specifically, after their full review, all the selected articles were categorized and organized with the help of two tables (Appendices A and B). This data extraction process was very constructive in retrieving each study's desired information and research findings. Interestingly, the tables are easy to read and understand and include authors' names, year of publication, the time period of the empirical analysis, the country of research, variables of interest, the methodology followed, the econometric approach implemented, and the research results. To maximize the reliability of the present study, the data extraction was carefully made and double-checked by both authors to avoid mistakes (e.g., data entry errors) and misinterpretations of concepts and methodologies.

4. Developments in Energy Growth

The research purpose of this study is to review high-impact and contemporary studies in the field of EKC and energy growth nexus discussion and provide a robust empirical and reference framework within environmental economics. Over the years, and under different models that support economies, efforts have been put into practice to decode patterns and causalities that affect the relationship between energy and economic growth. The energy growth nexus concentrates on the influence of energy as a production factor in a nation's economy. Hence, conclusions can be drawn concerning the sensitivity of economic growth towards energy conservation measures to limit relevant consumption and protect the good ecological status of the environment (e.g., air quality and CO_2 emissions, use of fossil fuels) [22]. The root cause behind such an attempt stems from the need to search for unobserved or less visible or overlooked dynamics and factors that impact energy use and provide evidence of the necessity to form a responsible character in resource exploitation (e.g., oil, gas) in view of future energy outlooks and linkages with economic growth. Such causalities are then evidenced on the basis of the following four hypotheses [23–25]: the growth, conservation, feedback, and neutrality hypotheses. The growth hypothesis indicates a unidirectional causality from energy consumption to economic growth. The conservation hypothesis suggests a unidirectional causality from economic growth to energy consumption. The feedback hypothesis justifies a bidirectional link between energy consumption and economic growth and vice versa. The neutrality hypothesis evidences no causality relationship between energy consumption and economic growth. The growth hypothesis indicates that countries are energy dependent, and that increases (decreases) in the energy consumption rates drive increases (decreases) in the economy. The conservation hypothesis suggests that countries are less energy dependent, and that measures taken to limit energy consumption rates do not impact (positively or negatively) the economy. This economy is more sustainable, at least in terms of energy consumption issues. The feedback hypothesis justifies a two-sided linkage indicating that changes in energy consumption patterns lead to changes in economic growth in the same direction and vice versa. This hypothesis shows that complementarities between the economy and the energy sector exist. The neutrality hypothesis suggests that economic growth is affected by factors other than energy consumption rates. The issue of considering studies that concern aggregate measures of energy consumption compared with studies that elaborate on disaggregate proxies is highlighted. This disaggregated investigation brings the changeover to a green economy closer, in terms of using clean energy [26]. In an effort to focus on specific measures that better help perceive the impact of energy on economic activity, Ref. [27] included the Renewable Energy Country Attractiveness Index (RECAI) proposed by Ernst & Young Global Limited. This energy proxy concerns each market's macroeconomic variables, technology-related issues, and energy-specific factors.

Supportively, the significance of shifting the energy mix towards a renewable energy matrix is framed in the seventh Sustainable Development Goal (SDG7). A research effort that elaborates on the economic dimension of sustainable development should seriously consider the Sustainable Development Goals (SDGs) as part of the broader 2030 Agenda for bringing a sustainable future closer to our reality. To this effort, [28] tested 35 indicators linked to the economic SDGs (SDG 7, SDG 8, SDG 9, SDG 11, and SDG 12), applying a multicriteria analysis for 27 European countries. The core purpose was to form an aggregate value of sustainability. The test results indicated that, given the multidisciplinary nature of sustainability, for most countries, the tested aggregate sustainability indicator showed a good linear fit with GDP per capita. The proposed aggregate indicator captures economic sustainability but is also concerned with the effects on the other two pillars: society and the environment. Research findings indicate that economic growth accompanied by tax havens does not follow the same direction of economic sustainability as determined by the SDGs (for instance, the cases of Luxemburg and Ireland).

Perceiving the determinants that compose the non-renewable energy consumption patterns contributes to improving the strategy and implementation of environmental mitigation plans [29]. For instance, [30] disaggregated energy consumption into renewables (e.g., hydroelectric power, geothermal, solar, wind, and biomass) and nonrenewable sources of energy (e.g., natural gas, coal, and petroleum), and a distinction based on sector (e.g., renewable and nonrenewable sources in terms of industrial, commercial, and residential) was attempted by [31,32]. Interestingly, it should be noted that the research results derived from the literature are mixed even when the energy mix is disaggregated [27].

Furthermore, one particular aim for distinguishing energy between renewables and non-renewables is to consider fluctuations in oil prices, dysfunctions in import and export processes, and energy security aspects within the economic system [33]. In the same direction, energy poverty is a thorny problem that concerns many countries worldwide (e.g., developing and developed countries), and potential mitigation phenomena might impact a country's social welfare [34]. Energy poverty widely interrelates the supply side and accessibility issues as it concerns low-income and increasing energy prices globally [34]. Increased energy demand supports integrating renewables into long-term global policies to protect the environment [35]. All these aspects are considered in the energy growth nexus discussion in favor of establishing green growth patterns and viability in economic activities [36].

Many studies in the field use the nation's GDP as a growth variable to denote the concept of economic growth. GDP remains the 'world's most powerful number' (Fioramonti, 2013 [37]); however, it does not consider all dimensions of sustainable development, namely the environmental and social aspects of the growth process. To this effort, the Index of Sustainable Economic Welfare (ISEW) was included in the literature as a macroeconomic variable to test causalities with energy-related variables [22,38]. The key point behind such an approach was to see the concept of growth or development in an integrated, holistic way, not only in purely monetary terms but as an approach that might affect the welfare status and environmental health of the natural environment. Specifically, GDP does not discriminate welfare-improving activity from welfare-reducing activity [39]. From this perceptive, some major questions arise. For instance, can this number mirror any aspect of quality of life beyond financial terms? Or, even better, does the current socio-economic status allow for resting only in economic dimensions of well-being? [40] argues that research has been intensively put into practice to study measurements of well-being, including a more holistic vision of the development and welfare of a country. Consequently, additional measures and dimensions that depict the determination of well-being at the interface of energy and economy should be investigated in a more comprehensive, complete, and wide-ranging way. This is where the ISEW measure comes into the equation since it considers the benefits and the costs related to the economy instead of merely considering the market value of goods and services derived from production within the economy, as the GDP does [41]. The ISEW, developed by Daly and Cobb in 1989, offers a more robust picture of well-being status in society than GDP does since it inherently refers to variables that are not met in the conventional national accounts (e.g., social and environmental aspects) [42]. To better specify the concept of ISEW, researchers disaggregated this measure into the basic Index for Sustainable Economic Welfare (BISEW), which consists of only economy-related variables, and the Solid Index for Sustainable Economic Welfare (SISEW), which additionally includes environmental proxies [22].

Acknowledging the dominating factor of tourism in the global economy and its ecological footprint on the environment [43], researchers extended the energy growth nexus discussion into the tourism energy growth nexus discussion. In this case, the travel and tourism industry should reduce energy consumption rates from traditional resources while increasing renewables' contribution to consumed energy in light of experiencing tourism expansion within a sustainable economy [44]. Understandably, the sustainable development goals (no 13) have reported that the sustainable tourism sector, which limits its impact on climate change conditions and reduces the use of nonrenewable energy sources (e.g., fossil fuels), constitutes the main source of environmental degradation [45,46]. In this direction, Ref. [47] assert that economic development needs investment and a tourism sector that advances the concept of sustainability.

Given that the concerns over the loss, damage, destruction, or obscuring of ecosystems are widespread, the multifaceted character of the energy system allows for conceptualizing its scientific impacts on ecological status, quality levels, and ecosystem functions. Carbon emissions, the increased use of fossil fuels, the greenhouse phenomenon, global warming, and air pollution are among the environmental problems that need to be addressed to safeguard our future and minimize the negative effects on the world that future generations will inherit from us. A smooth transition into more reliable, efficient, and targeted energy policies should be encouraged and put into immediate practice as a response that maximizes the availability of energy for future purposes. Appendix A presents selected studies concerning the energy growth nexus.

5. Environmental Kuznets Curve (EKC)

The main research objective of this section is to analyze and synthesize how researchers conceptualized environmental degradation and contextualized the growth variables when testing the EKC hypothesis. Specifically, this section elaborates on reviewed test results to analyze multiple indicators that reflect environmental pollution and the growth process and thus comprehend environmental performance at its interface with the economy. Economic systems inevitably need and use ecosystem services to further expand and produce more to cover market and consumer demands. In this growth process, the environmental dimension dominates the efforts to remain sustainable and viable within volatile market conditions and against severe competition. Such a relationship between the environment and the economy is investigated by testing the EKC hypothesis. The EKC specifies that environmental deterioration levels rise in the first phases of a nation's economic growth process [1,2]. After a specific point in this growth process, environmental degradation levels decrease [1,2]. This linkage is expressed by an inverted U-shaped curve [2] or, in some cases, by an N-shaped curve [48,49]. This nonlinear character of the EKC has been justified in the literature, reflecting the relationship between the macroeconomic nature of the economy and the quality levels in the environment.

The initial idea of this approach was first developed by [50]. Practically, Kuznets argued that, in the process of economic growth and due to market conditions ('forces'), income inequalities first increase and then decrease, indicating a nonlinear form. This hypothesis was integrated to decode the linkage between economic variables and environmental proxies. Then, researchers formed the so-called EKC with a great magnitude of applicability, enriching the relevant literature. This process widely facilitates policymakers to foster environmental management plans without losing the business potential within an economic system. Noticeably, the growth process has changed the interaction effects of the natural environment and market forces at the interface of environmental quality levels and sustainability concerns [51].

Not surprisingly, researchers used a wide range of indicators to reflect the growth process and the environmental degradation levels. As expected, different pollutant variables have different turning points after which the environmental degradation does not develop further [52]. For instance, Ref. [53] tested the EKC by adopting ecological and material footprints concerning the consumption perspective, whereas [54] explored the impact on the environment (e.g., industrial wastewater and sulfur dioxide) of economic growth and trade openness. Notably, Ref. [55], based on a robust literature review on the investigation of the EKC theory, argue that there is no obvious sign to fit all pollutants to all selected proxies, places, and time spans of the research. Interestingly, a noticeable research study in the field of EKC implemented by [56] indicates that a U-shaped quadratic link is formed between economic growth (GDP) and environmental degradation (pollution level) concerning the South Asian Association for Regional Cooperation (SAARC) countries. Research findings reveal that pollution levels are caused by using fossil fuels, while renewable energy and nuclear energy limit pollution extensively. The need to use sustainable energy sources and protect the environment is essential and results in limiting harmful greenhouse gas emissions. Furthermore, the test results suggest the use of technological advancements and environmental laws to improve the levels of environmental quality.

According to [57], the literature on the EKC can be categorized into three main approaches. The first category concerns studies related to carbon dioxide, sulphur releases, and suspended particulate matter. The second category includes indicators connected with the ecological status of water-related variables (e.g., wastewater, water footprint, water use, and seawater quality). The third category encompasses proxies that reflect the quality levels of land in terms of plastic waste, municipal waste, and medical waste. Furthermore, [58] state that the EKC literature discloses two primary sets of pollutants. The first category interrelates air pollution (e.g., CO_2, SO_2, NO_x, CO emissions). The other concerns water pollution status and relevant environmental indicators regarding heavy metals and pathogens.

Empirical research attempts included multiple indicators and proxies to confirm or not the inverted U-shape relationship suggested by the EKC analysis. Indicatively, deforestation was a source of environmental degradation [59–61]. As indicated in the work of [36], additional research efforts used international trade [62], energy consumption [63], renewable energy [64–66], and technological innovation [66] as variables to test the EKC framework.

The EKC conceptual framework does not lack criticism. Numerous econometric problems impact the explanation of EKC test results, indicating econometric weakness [59]. Refs. [59,67] claims that omitted variables bias is an issue. Furthermore, integrated variables, spurious regression phenomena, and the time effects identification raise difficulties in interpreting EKC estimates [67]. Ref. [67] further argues for alternative econometric approaches to perceive the 'income-emissions' relationship. Based on decomposition analysis, receiving more meaningful and interpretable results would be beneficial. For instance, researchers can rely on specific indicators (e.g., index numbers) and detailed sectoral data on fuel use, production, and emissions. Another approach to determining the linkage between the economy and environmental degradation levels is the convergence hypothesis. This approach suggests that pollution levels decrease faster in highly polluted countries than in countries with low pollution levels or decreases in the former and increases in the latter. Specifically, in the first stages, if rich countries are highly polluted and poor countries are lowly polluted, the outcome will potentially resemble the EKC hypothesis [67].

In the literature, special attention has been paid to the Tourism-Induced EKC (T-EKC). This approach allows the integration of additional variables into the ECK equation beyond the traditional GDP per capita. Tourism proxies or indicators are important to perceive relevant growth limits in the context of environmental sustainability [68]. Such high-impact industries and the growth created in destinations can affect the relationship between the relevant economic activity and environmental quality levels. Supportively, [69] states that the per capita income is not the only causal growth variable used to define the negative sloping downward EKC. Furthermore, additional tourism-related variables were used to test the EKC conceptual framework. Interestingly, as indicated in the work of [36], tourism arrivals, receipts, revenues, and international tourism expenditures were adopted to investigate the impacts of tourism on the environment or to test the EKC hypothesis (indicatively [70–75]. These studies conceptualized tourism as a homogenous bundle of activities or phenomena.

On the contrary, Refs. [36,76] proposed a different disaggregated approach. They tested tourism proxies as growth variables (e.g., the direct contribution of tourism to a nation's GDP and business and leisure market segments) to confirm the U-shaped curve suggested by the T-EKC. With this approach, researchers can focus on specific high-leverage segments of economic activity and investigate their ecological footprint (e.g., air quality and CO_2 emissions). Consequently, opportunities for further research appear to consider tourism as a dynamic system with discrete components (e.g., segments) that develop in time and space based on its inherent multivariate nature. Moreover, Ref. [77] assert that tourism demand segmentation is essential for effective management plans concerning resource protection issues. Appendix B presents selected studies concerning the EKC hypothesis.

6. Discussion and Implications

The review process disclosed that the concept of energy efficiency constitutes a valuable and beneficial means of achieving an environmentally friendly mode without losing much from business potential and relevant economic targets. This is especially true when examining relationships between energy consumption and growth variables (e.g., GDP). Furthermore, the concept of "sustainable GDP" (e.g., ISEW) should be highlighted when investigating linkages at the interface of the economy and energy. This approach will benefit and progress relevant research efforts toward a new mindset, a mindset that calls for seeing the environment and energy consumption patterns as a source of sustainability (e.g., continue receiving ecosystem benefits for the long run) instead of testing strictly economic variables (e.g., the traditional GDP) and considering growth in purely monetary terms.

Moreover, using the same logic, researchers should concentrate on additional explanatory variables to better perceive their predictive power over environmental quality levels or economic performance. Tourism-related variables may offer useful, meaningful, and interpretable research findings. They might offer insights and inputs given the significance and importance of tourism in the economic system, not only at a regional level but also at a national and international level.

The reviewed research findings can be incorporated into environmental and energy management plans based on their dependability and scientific justification established by robust econometric models. These decisions will, in turn, generate applicable environmental policies and maximize margins for acting, individually and collectively, in a safe and healthy environment. Moreover, the social dimension of sustainability should be considered a fundamental determinant when testing the EKC hypothesis or discussing development in energy growth. Indicators to capture social sustainability are characterized by diversity and should include social cohesion, bonds, social infrastructure, and social justice. Notably, many research efforts include the concept of Corporate Social Responsibility as an answer to adapt to sustainability challenges [78]. Given that the economic pillar has currently gained the most notice, the social dimension is of high importance since it stresses the role of firms' impact on societal aspects such as relations in the community, charities, and social support [79].

Authors should discuss the results and how they can be interpreted from the perspective of previous studies and working hypotheses. Intense economic activities and unbalanced policies (e.g., poor energy management and fossil fuel use) supported by conventional management methods made natural ecosystems vulnerable and seriously damaged natural processes. Hence, natural resources and energy are treated extensively on a large ('massive') scale to fuel economic growth and create environmental degradation [80]. Natural systems are in danger of unmanaged human interventions, ineffective sectoral policies, habitat destruction, and resource overexploitation. Consequently, this aspect of environmental degradation became a popular research issue, especially after the work of [80]. Then, a considerable number of outstanding research studies were put into the process to gauge the environmental impacts of economic performance considering many indicators [81].

Over time, such behavior increasingly raised concerns about challenges related to resource quality, availability, consumption, and market potential (e.g., market failure), not to mention population growth and demand projections. Practically, the relationship between environmental quality and macroeconomic variables is significant in establishing policies, for instance, fiscal policies on carbon dioxide emissions [82]. In particular, concerns have arisen over the optimum balance between use—users and demand—growth. For decision-makers, a paradigm shift that recognizes cross-sectoral externalities and explores feasible trade-offs is highly needed so as to achieve greater policy coherence [83]. This is the case for high-leverage economic sectors such as tourism. In this context, tourism development policies define the adverse effects of tourism indicators on environmental degradation followed so far as improving the energy structure is important for achieving superior environmental performance and quality [84]. Such an argument calls for resource efficiency to experience better energy savings rates and control emission releases [85].

Research efforts on the energy growth nexus discussion and the EKC bring to the surface the imperative need to act in a safe and healthy environment to ensure social and human well-being and sustainability. To clarify, achieving a low-GHG emissions economy is a thorny problem in our modern world. Recognizing factors influencing GHG emissions releases constitutes a current issue in our reality [86]. The concept of green growth dominates all research implications since it advances economic viability and the sustainable use of resources and considers environmental impacts [87]. To support this, European Commission officials proposed the Green Deal agreement, an ambitious plan for becoming the world's first climate-neutral continent. Significantly, the Sustainable Development Goals under the United Nations call for immediate internationally agreed and integrated actions to combat energy poverty, protect the planet, and 'prioritize progress for those who are furthest behind' and achieve the anticipated balance between nature and socioeconomic systems [88].

Many researchers identified the key role of energy patterns (primary and final energy consumption), energy type (renewables nonrenewable), and source (industrial, commercial, household) when elaborating on the impacts and causalities between economic activity and the environment (indicatively, Refs. [22,30,76]). Growth in demand leads to major shifts in the way that individuals and nature interact, in the scale at which this occurs, and most notably, in the environmental schemes in which this happens. The fundamental aspect behind such a situation is the concept of energy efficiency in the context of technology and renewable sources [36]. The Index of Sustainable Economic Welfare (ISEW) is used as a proxy of Sustainable GDP [89], adjusting the traditional GDP used. This concept was first launched in relevant research efforts by [90] and received further improvements by [91]. ISEW is an indicator to overcome limitations derived from traditional GDP measures viz externalities, income distribution, and natural resource depletion [92]. It indicates a closer-to-reality ("down-to-earth") approach to human and societal well-being compared with traditional GDP [42]. Additionally, ISEW constitutes a means for evaluating social and environmental costs [93].

Collective action is required at all levels of governance and various sectors that structure a nation's economy to deploy initiatives and high-leverage contributions to form cohesive environmental and energy policies (supply and demand, production and consumption, exports and imports, energy type, source, and form) that are mutually agreed and consistent with goals set in the long run. Despite the promising character of such endeavors, there are obstacles in managing energy issues within this new but demanding potential. Technological advancements support the EKC argument by limiting energy intensity, advancing recycling rates, and increasing total factor productivity in the production processes [58]. Even with the long-term perspective of this effort, thorough energy management still faces notable challenges. These include the lack of economic resources, financial support, and funding and business hesitation, reluctance, and economic uncertainty to proceed with viable investments. It is worth saying that there is a great need to perceive the extent to which energy allocation will become efficient, indicating positive impacts on sustainable growth to advance environmental improvements without restricting economic growth [94]. For instance, [86] reported that we are experiencing climate changes due to severe greenhouse gas emissions, which in turn cause negative effects on the sustainable magnification of economies.

It has been observed that an unwillingness to change consumptive behavior and a lack of information and openness to new visions restrict investments or question potential gains from European-funded projects. Such a situation mirrors the so-called 'energy efficiency gap' (between actual and optimal energy use) that existed decades ago (see [95] or the 'energy paradox'. Since estimations regarding relevant costs and benefits remain controversial (see [96]. Investments in energy-efficient innovations for minimizing energy costs and environmental damages connected with energy consumption behavior should be put into practice. Logically, a 'what if scenario' arises, meaning what if nations spend (invest) such an amount but do not receive positive feedback (reap energy productivity benefits) related to the desired long-lasting results (energy efficiency targets) of the (cost-effective) investment? To be more precise, will the whole endeavor yield and distribute quantifiable benefits to society (e.g., households and the business world)? Will stakeholders recognize, realize, and capture such gains? Possibly, such questions need empirical answers based on data processing and scientific research that considers space and time and cross-country differences in energy productivity levels. Such an attempt may help identify causes that drive economies to become more or less energy productive and that frame a global perspective. For instance, financial integration and ICT technologies can have long-term impacts on the environment regarding sustainability [87,97].

As is the case with any studies for contemporary issues, research findings provide contradictory results [27]. Scientists have yet to agree on whether energy drives economic growth or vice versa. The same is true when the EKC is tested. The common reason for such a situation is the use of bivariate or trivariate models resulting in omitting variable bias. Another issue is that some researchers prefer time series analysis over panel data analysis. Additionally, data spans and data availability constraints are relevant to research efforts. Furthermore, researchers might not disaggregate the phenomenon they wish to elaborate on (e.g., energy in terms of sector and source, tourism in terms of market segments), creating differentiations in results.

7. Conclusions

The extent to which desired sustainability levels have been achieved has deeply depended on the ability of individuals and/or communities to adopt changes and challenges, to take initiatives, and to accept innovations and involvement in their use of technologies, databases and systems, information, and communication channels.

All efforts are focused on specific and measurable objectives that are strong enough to remove obstacles and delays towards green growth within environmental ethics and respect for all living and non-living things, namely biodiversity and geodiversity. In achieving this effort, great importance is attached to empirical studies. Based on dependable research findings, such efforts add extra value to the whole endeavor for multiple stakeholders within the environmental management system. Key points in the literature are the use of renewable sources of energy in industry and households, while carbon dioxide emissions must be limited to zero releases by 2050. Concepts such as the ISEW provide a solid base on which research can be put into the process.

These studies can be used as tools to inform every and each part of the environment–energy–economy system and build trust to overcome barriers to becoming efficient and, in turn, energy productive. They can be used to strengthen the targeted use of innovations without losing an opportunity (hopefully not the last one) to share research findings with theoretical and practical implications that highlight the benefits of creating safer and enjoying smarter initiatives in the long run. Arguably, translating the body of knowledge into learning and educational insights for fostering an ecological perspective and advancing the commitment to diffuse research findings in every host society stimulates its interest in gaining environmental knowledge through active support, participation, and involvement.

Judging from the outstanding work of all the reviewed studies, new research opportunities arise on the basis of additional variables used to view the phenomenon in question holistically. The relationship between energy and growth still remains an issue that deserves our attention and requires further research over the years, not to mention the goal of securing social bonds and cultural integrity. If our culture/mindset fails to efficiently exploit the natural environment and ecosystem goods and services, then failures to achieve sustainable development and enjoyable well-being occur. One particular limitation of the present work is that we have examined papers published after the year 2000. Although many researchers investigated the links between the environment and the economy in the 1990s, we have included only publications from the last two decades to highlight contemporary new trends and research efforts. Moreover, the present study offers opportunities for future research efforts. We believe that new market segments derived from high-leverage economic sub-sectors (e.g., as core determinants) and additional growth variables beyond the conventional GDP should be used when elaborating on the EKC hypothesis and developments in energy growth.

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Appendix A

Table A1. Relationship between Energy and Economy (Energy Growth Nexus).

Authors	Period	Country	Variables	Methodology	Causality
[98]	1995–2005	Six countries: Argentina, France, Germany, Korea, Pakistan, and Switzerland	GDP nuclear energy consumption	Granger causality test	Switzerland: feedback hypothesis France and Pakistan: conventional hypothesis Korea: growth hypothesis Argentina and Germany: neutrality hypothesis
[23]	1980–2006	Six Central American countries	GDP renewable energy consumption, real gross fixed capital formation, labor	FMOLS Engle–Granger two-step procedure	Feedback hypothesis for GDP and energy consumption (short and long run)
[99]	1980–2012	Fifteen OECD countries	GDP nuclear energy consumption, fixed capital formation, labor force	Bootstrap causality test developed by Hacker and Hatemi-J (2006) Toda Yamamoto (1995) causality test	Neutrality hypothesis 10 out of 15 OECD countries based on bootstrap-corrected causality test Neutrality hypothesis is supported for 8 OECD countries BASD ON Toda Yamamoto (1995) causality test
[100]	1970–2011	Sixteen Asian Pacific countries	GDP, energy consumption, physical capital, labor, human capita	Continuously updated fully modified estimation Bootstrap panel Granger causality test	Conventional hypothesis from GDP to energy use, Results vary for individual countries
[101]	1980–2010	Four Asian countries	GDP, electricity consumption, labor, capital	Random effects modeling	Growth hypothesis from electricity consumption to economic growth
[102]	1990–2013	Nine developed countries	GDP pc, nuclear energy consumption, CO_2 emissions, renewable energy, capital, labor	Panel causality test	Growth hypothesis for renewable energy consumption for all panels at the short run Neutrality hypothesis for nuclear energy and GDP pc

Table A1. *Cont.*

Authors	Period	Country	Variables	Methodology	Causality
[38]	1995–2013	G7 countries	ISEW pc, BISEW pc, GDP pc, total energy consumption pc, fixed capital formation, total labor force, research and development, expenditures per capita	Panel ARDL model PMG estimator	Feedback hypothesis for ISEW pc and energy Growth hypothesis from energy to the BISEW pc Conventional hypothesis from ISEW pc BISEW pc GDP pc energy consumption
[22]	1990–2015	Eighteen selected Asian countries	ISEW pc, BISEW pc, GDP pc, non-renewable energy consumption (NREN), renewable energy consumption (REN), trade, rents, financial development, inflation	Panel analysis Westerlund (2007) cointegration tests Dumitrescu and Hurlin (2012) Granger noncausality tests	Feedback hypothesis for ISEW pc Feedback hypothesis for BISEW pc Feedback hypothesis for GDP pc
[103]	1965–2015	Global level	Real global GDP	VAR methodology	Feedback hypothesis
[104]	1980–1994 1995–2016 (structural break in 1995)	Vietnam	GDP pc, energy consumption, total global aggregate primary energy consumption	ARDL Toda and Yamamoto (1995) Granger causality test	Feedback hypothesis from GHDP to energy consumption
[105]	1971–2014,	Malaysia	GDP pc, energy consumption pc, capital, labor, and urbanization	ARDL bound test Granger causality results	Mixed results in the short run and the long run.
[106]	1990–2017	BRICS and ASEAN countries	GDP pc, energy use pc, international trade pc and Foreign Direct Investment pc (FDI), capital stock pc, labor pc	Fixed effects panel quantile regression Granger noncausality test	Feedback hypothesis was confirmed
[107]	1984–2013	Eleven countries	GDP, energy consumption, index for globalization	Panel causality test based on Seemingly Unrelated Regressions (SUR) system	Feedback hypothesis for Egypt, Indonesia, Iran, South Korea, Nigeria, and Turkey
[108]	2002–2021	Ten nuclear energy-consuming countries from the European Union	GDP, nuclear energy consumption, renewable energy consumption, gross fixed capital formation, labor		Feedback hypothesis for nuclear energy Growth hypothesis for renewable energy

Appendix B

Table A2. Testing the EKC Hypothesis.

Authors	Period	Country	Variables	Methodology	EKC Hypothesis
[1]	1960–1990	Seventy-three OECD and non-OECD countries	GDP pc, sulfur emissions	First-time random coefficients and Arellano–Bond Generalized Method of Moments (A–B GMM) econometric methods	EKC confirmed for A–B GMM EKC not confirmed for first-time random coefficients
[2]	1950–2003	Ninety-seven European and non-European countries	GDP pc, sulfur emissions	Westerlund ECM panel cointegration tests Fixed effects with Driscoll–Kraay standard errors	EKC confirmed
[109]	1960–2010	Forty-eight US States	Real personal income pc, CO_2 pc	Common Correlated Effects (CCE) estimation	EKC confirmed for 10 states
[110]	1980–2002	Seventeen OECD countries	GDP pc, constructed environmental efficiency ratio	Data envelopment (DEA) window analysis generalized method of moments (GMM)	EKC not confirmed
[111]	1970–2013	Four selected ASEAN countries	GDP pc, CO_2 pc	OLS, FMOLS, and DOLS methods	EKC not confirmed
[112]	1990–2014	Canadian and provincial/territorial levels	Greenhouse gas emissions	Pooled regression fixed-effects regression	EKC confirmed at the Canadian level EKC confirmed for five out of ten provincial/territorial levels (under pooled regression) EKC confirmed for all provincial/territorial levels (under fixed-effects regression) EKC confirmed at the Canadian level, and in all provinces and territories
[113]	1971–2013	Australia, China, Ghana, and the USA	GDP, CO_2	PMG estimator	EKC confirmed (China)
[114]	1992–2014	BRICS countries	GDP pc, CO_2 pc	Panel cointegration methods (DOLS)	EKC confirmed
[115]	1995–2013	Thirty China provinces	GDP, CO_2,	Spatial regression Cubic models	N-shape curve
[116]	1970–2018	Greenland (Arctic region)	real GDP pc CO_2, total electricity production, urban population	Autoregressive distributed lag (ARDL)	EKC not confirmed
[117]	1995–2016	Central European countries	CO_2 pc, real GDP pc, energy use pc, trade openness,	Autoregressive distributed lag bound testing	EKC confirmed only in Poland

Table A2. *Cont.*

Authors	Period	Country	Variables	Methodology	EKC Hypothesis
[36]	1996–2019	Eurozone countries	GDP pc Direct contribution of tourism to GDP pc (dcgdppc), greenhouse gas emissions pc	Fixed effects with Driscoll– Kraay standard errors	EKC confirmed for GDP pc EKC confirmed for dcgdppc
[76]	1996–2019	Eurozone countries	Business tourism spending pc (btspc), leisure tourism spending (ltspc), greenhouse gas emissions pc	Fixed effects with Driscoll–Kraay standard errors	EKC confirmed for btspc EKC confirmed for ltspc
[56]	1982–2021	South Asian Association for Regional Cooperation (SAARC)	GDP, GHGs emissions, fossil fuels, renewable energy, nuclear energy	Second-generation unit root test, cointegration test, AMG technique	EKC not confirmed in SAARC countries

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