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Framework for Determining the Role of Renewable Energy in Economic Growth and Sustainability: A Saudi Arabia Perspective

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Abstract

This paper proposes a framework to examine the significant role of renewable energy in promoting sustainable economic growth within the Kingdom of Saudi Arabia. The research delves into the existing energy landscape, highlighting the limitations of traditional fossil fuels and their adverse environmental effects. The need for a transformative approach, driven by renewable energy sources, underscores the current study's objective. The research thus identifies a gap in understanding the full economic impact of a renewable energy strategy, especially in a nation deeply rooted in oil dependency. The problem this study addresses is how renewable energy can serve as a catalyst for economic diversification and growth, reducing reliance on fossil fuels and fostering sustainability. The primary objectives of this research are: first, assessing the status and efficacy of Saudi Arabia's renewable energy policies, second, evaluating the impact of these policies on economic development and job creation, and last, proposing a framework for measuring renewable energy's contribution to economic sustainability. This paper's proposed framework integrates government policies, renewable energy initiatives, and economic metrics to comprehensively analyze renewable energy's role. The study concludes that renewable energy is a critical pathway for Saudi Arabia's economic future, offering sustainable solutions to resource scarcity, job creation, and environmental conservation. Future research will provide in-depth analyses of policy frameworks and technological advancements to support Saudi Arabia's economic transformation.

Keywords: Economic Growth, Energy Policy, Renewable Energy, Saudi Arabia, Sustainability

Introduction

Amid growing environmental and economic concerns, the urgency to transition from fossil fuels to renewable energy has gained considerable attention (Mutezo & Mulopo, 2021; Holechek et al., 2022; Depren et al., 2022; Al-Ismail et al., 2023). Currently, fossil fuels account for about 80% of global energy consumption, despite their finite nature and detrimental environmental impact (Holechek et al., 2022; Depren et al., 2022). Their widespread use has led to escalating greenhouse gas emissions, climate change, and ecological damage,

prompting nations to prioritize cleaner energy alternatives such as solar, wind, and geothermal energy. Saudi Arabia, a leading oil producer, faces similar challenges. While traditionally reliant on its abundant oil reserves, the Kingdom has made significant strides toward integrating renewable energy into its economy. This transition reflects both national and global priorities, positioning Saudi Arabia to align with international sustainability objectives while ensuring its long-term economic resilience.

Energy is a fundamental component of economic development, influencing various aspects of society, from industrial productivity to healthcare and education (Jie, 2023). As countries transition to a renewable economy, they reduce carbon emissions, enhance energy security, and create economic resilience against the volatility of fossil fuel markets (Genc & Kosempel, 2023). For Saudi Arabia, this transition is particularly critical. The Kingdom's heavy dependence on oil revenues makes it vulnerable to fluctuating oil prices, and its high energy consumption rate places additional strain on its resources (Remsey, 2023). Rapid population growth and economic expansion have only intensified energy demands, underscoring the necessity for Saudi Arabia to diversify its energy sources. By investing in renewable energy, Saudi Arabia aims to free up more of its oil reserves for export rather than domestic consumption, improve air quality, reduce greenhouse gas emissions, and create new economic and employment opportunities in the renewable sector (Remsey, 2023; Salem *et al*., 2023; Abdelkawy & Al Shammre, 2024).

However, the economic implications of this transition remain underexplored, particularly in a country like Saudi Arabia, where fossil fuels have long been the backbone of its economy (Remsey, 2023). As such, this research aims to address a critical gap: understanding the economic impact of renewable energy strategies on the Kingdom's growth and sustainability. Transitioning to renewable energy is not just an environmental initiative; it is an economic imperative that requires robust policy frameworks, technological advancements, and strategic investment in renewable infrastructure. The Kingdom's Vision 2030 plan underscores this commitment, identifying renewable energy as a cornerstone of economic diversification and environmental stewardship. Yet, questions remain about the efficacy of these initiatives, the economic viability of renewable projects, and the potential challenges in integrating renewables within Saudi Arabia's existing energy infrastructure.

This research sets forth a framework for evaluating Saudi Arabia's renewable energy strategy in terms of its economic benefits, policy effectiveness, and potential for sustainable growth. Specifically, it examines the Kingdom's current renewable energy initiatives, assesses the impact of these efforts on economic development, and explores the role of policy in facilitating the transition. The primary objectives are to clarify the status of renewable energy resources in Saudi Arabia, evaluate the Kingdom's renewable energy programs and policies, and study how these strategies contribute to economic revitalization and poverty alleviation through job creation and investment.

This paper is particularly relevant as Saudi Arabia's renewable energy sector is poised to become a global model for sustainability, demonstrating how even oil-rich nations can transition toward greener economies. By focusing on both the scientific and practical implications of renewable energy, this paper contributes to the existing body of knowledge on sustainable economic development. It highlights the essential role that renewable energy

plays in meeting Saudi Arabia's economic needs, addressing environmental concerns, and positioning the Kingdom as a leader in the global green economy. Ultimately, this research not only provides insights into the transformative potential of renewable energy for Saudi Arabia's economy but also underscores the need for a comprehensive framework that aligns economic, social, and environmental objectives. The findings of this study will be invaluable for policymakers, stakeholders, and researchers interested in the intersection of energy, economics, and sustainability, paving the way for a future where economic growth and environmental stewardship go hand in hand.

Literature Review

The global transition from conventional energy sources to renewable and sustainable alternatives has spurred extensive research into the interconnected dynamics of energy, economic growth, and environmental sustainability. As one of the world's leading oil producers, Saudi Arabia encounters distinct challenges and opportunities in this transition, particularly given its dependence on fossil fuels and the ambitious objectives set forth in its Vision 2030 initiative. This section reviews existing literature on renewable energy's impact on economic growth, environmental sustainability, and diversification strategies within the Saudi Arabian context and beyond. Key studies explore various dimensions of energy consumption and sustainability, such as the role of renewable energy in reducing carbon emissions, the contribution of blue and green economic indicators to growth, and the implications of fossil fuel dependence. This review highlights significant findings, methodological approaches, and gaps in the literature to frame the research's contribution to understanding how renewable energy strategies can align economic growth with sustainability objectives. By examining these interconnected factors, the literature underscores the critical need for policy innovations, investment in clean energy, and a nuanced understanding of regional energy dynamics to promote sustainable economic transformation in resource-dependent economies like Saudi Arabia.

Related Works

Raihan and Tuspekova (2022) aim to explore the dynamic interplay of economic growth, fossil fuel consumption, renewable energy use, and technological innovation on CO_2 emissions in Kazakhstan. The study seeks to provide insights into achieving environmental sustainability in a fossil fuel-reliant economy by identifying key drivers of emissions and potential pathways for reductions. This study addresses a key gap by focusing on Kazakhstan's energy consumption and greenhouse gas emissions challenges. It explores the relationships between economic growth (GDP per capita), fossil fuel energy use, renewable energy use, and technological innovation (measured by patent applications), with CO_2 emissions as the dependent variable representing environmental impact. Using data from 1996 to 2018, the analysis employs the Dynamic Ordinary Least Squares (DOLS) method, supported by Fully Modified Ordinary Least Squares (FMOLS) and Canonical Cointegrating Regression (CCR) for robustness. Stationarity of the data was confirmed through unit root tests, including the Augmented Dickey-Fuller (ADF) and Phillips-Perron (P-P) tests.

The findings indicate that economic growth and fossil fuel consumption significantly increase CO_2 emissions, highlighting their detrimental impact on environmental sustainability. In contrast, renewable energy use and technological innovation are found to reduce CO_2 emissions, with renewable energy having the most pronounced effect. The study emphasizes

the importance of transitioning from fossil fuels to renewables and fostering technological advancements to achieve sustainability goals. These insights are particularly relevant for policymakers aiming to promote a low-carbon economy in Kazakhstan through renewable energy incentives and technological innovation. Despite its strengths, the paper has several shortcomings. The focus on CO_2 emissions as the sole measure of environmental degradation limits the scope of the analysis, as it overlooks other critical environmental indicators such as water and land pollution. Additionally, the study's reliance on data from 1996 to 2018 excludes more recent developments in Kazakhstan's energy sector and climate policies. The use of secondary data further restricts the inclusion of localized socio-economic and cultural factors that could influence energy and environmental outcomes. Moreover, while the paper acknowledges barriers to renewable energy adoption, it does not delve deeply into the underlying political, institutional, and economic constraints hindering progress.

Qudrat-Ullah and Nevo (2021) investigate the relationship between renewable energy adoption, environmental sustainability (proxied by CO_2 emissions), and economic growth across 37 African countries. The study aims to provide insights into how these variables interact, addressing key gaps in understanding sustainable development in Africa. Using panel data from 2008 to 2014 and the Generalized Method of Moments (GMM) technique, the authors examine short- and long-term impacts of renewable energy consumption on economic growth while considering environmental sustainability as a moderating factor.

The study reveals a positive correlation between renewable energy consumption and economic growth in Africa, where a 1% increase in renewable energy consumption results in a 0.07% rise in economic growth in the short term, with a greater effect over the long term. However, CO_2 emissions, representing environmental sustainability, show no statistically significant influence on economic growth. Furthermore, environmental sustainability does not significantly moderate the link between renewable energy consumption and economic growth, indicating that Africa's renewable energy policies operate largely independently of sustainability factors. A key strength of the study lies in its use of the GMM technique, which effectively addresses endogeneity and omitted variable bias. The analysis offers actionable policy insights, emphasizing the importance of renewable energy development for economic growth. However, the study is limited by its reliance on data from 2008 to 2014, which excludes recent advancements in renewable energy technologies and policies. Furthermore, the use of CO_2 emissions as the sole proxy for environmental sustainability overlooks other critical dimensions, such as land and water degradation. The lack of attention to socioeconomic and political factors that influence energy policies also limits the depth of the analysis.

In addition, Waheed *et al*. (2020) examine economic diversification as a means to reduce Saudi Arabia's dependency on oil exports and achieve sustainable growth, aligning with the Vision 2030 agenda. Utilizing quarterly data from 1980 to 2017 and applying econometric methods such as ARDL bounds testing, Johansen cointegration, and Gregory-Hansen cointegration, the study analyzes the interplay between non-oil exports, tourism, renewable energy, and economic growth. The results show that a 1% increase in non-oil exports leads to a 0.41% rise in GDP, underlining the importance of export diversification for economic stability. Tourism also contributes positively to growth, supporting the need for reforms in religious and cultural tourism. Although renewable energy has a significant long-term effect

on economic growth, its short-term impact remains limited due to high initial costs and infrastructure challenges. These findings align with Vision 2030's goals to reduce carbon emissions and expand renewable energy utilization.

While the study offers valuable policy insights, it has some limitations. The data only spans up to 2017, omitting recent developments in Saudi Arabia's economy and energy policy. Additionally, the focus is predominantly on GDP as an indicator of sustainability, leaving out other critical dimensions like environmental quality and social equity. The analysis also lacks a comparative perspective with other Gulf Cooperation Council (GCC) countries, which could have provided a broader regional context. Furthermore, the discussion on the challenges of transitioning to renewable energy remains underdeveloped.

Further, Kahia *et al*. (2021) explored the relationships between renewable energy consumption, economic growth, and environmental quality in Saudi Arabia from 1990 to 2016 using simultaneous equation modeling. Their findings reveal that economic growth promotes renewable energy consumption, supporting the conservation hypothesis. A bidirectional link between economic growth and CO_2 emissions shows that economic activity exacerbates environmental degradation, while emissions can hinder long-term growth. Additionally, the study identified a reciprocal relationship between CO_2 emissions and renewable energy consumption, indicating that higher emissions drive greater demand for renewables, which, in turn, help reduce emissions. The results also confirm the Environmental Kuznets Curve (EKC) hypothesis, showing that CO_2 emissions initially rise with economic growth but decline as income levels increase.

Despite its contributions, the paper has notable limitations. The dataset covers only up to 2016, potentially missing the impact of more recent renewable energy initiatives and advancements under Saudi Vision 2030. The analysis primarily focuses on CO_2 emissions, excluding other critical environmental metrics such as biodiversity loss or water quality. Additionally, the study does not explore socio-political barriers to renewable energy adoption, such as regulatory frameworks or public acceptance, which could provide a more comprehensive understanding of the challenges in transitioning to green energy.

Also, Kahia, Omri, and Jarraya (2021) investigate the interplay between renewable energy and economic growth in Saudi Arabia. The study, motivated by the country's high dependence on oil and its ambitions under Vision 2030, examines the extent to which renewable energy can offset the environmental degradation caused by economic growth. Using annual data from 1990 to 2016, the authors employ advanced econometric techniques, including Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS), to analyze the relationships among the variables. The findings indicate that economic growth significantly contributes to increased CO_2 emissions in all the models tested, emphasizing the environmental cost of the nation's development trajectory. While the Environmental Kuznets Curve (EKC) hypothesis is validated for CO_2 emissions from liquid fuel consumption, it is not supported for other emissions categories, suggesting that economic growth alone does not lead to environmental improvements. Renewable energy consumption exhibits a weak impact on reducing CO_2 emissions, and its interaction with economic growth does not significantly moderate the environmental degradation caused by economic activities. These results highlight the insufficiency of current renewable energy contributions to offset Saudi

Arabia's carbon footprint, underscoring the need for substantial policy and investment changes.

The study has several strengths, including its focus on a key global emitter, its rigorous econometric approach, and its use of multiple indicators for CO_2 emissions, such as emissions per capita, intensity, and emissions from specific sources like liquid fuels. However, the paper also has limitations. The dataset ends in 2016, excluding more recent developments in Saudi Arabia's energy policies. Additionally, the focus on CO_2 emissions as the sole environmental metric overlooks other critical aspects of sustainability, such as water and land degradation. The study also does not explore the socio-political and economic barriers to renewable energy adoption, which are crucial for understanding the feasibility of green energy transitions in Saudi Arabia.

AlNemer *et al*. (2023) explore the connections between renewable and non-renewable energy, CO_2 emissions, and GDP per capita in Saudi Arabia using spectral Granger causality analysis. The findings show that non-renewable energy significantly contributes to carbon emissions while supporting economic growth in the short and medium terms, though at the expense of environmental health. In contrast, renewable energy plays a vital role in reducing emissions and promoting economic growth across various time frequencies. Wavelet analysis reveals distinct disparities among the variables over the time-frequency spectrum, underscoring renewable energy's potential to drive sustainable economic growth and environmental improvements. The study emphasizes the importance of prioritizing investments in green energy and accelerating the shift to renewables, highlighting their substantial environmental, social, and economic advantages.

Waheed *et al*. (2023) examine the significance of blue indicators, such as sea trade and tourism, alongside energy and green factors, in driving sustainable economic growth in Saudi Arabia. Addressing a gap in prior studies, the research evaluates the role of blue economic factors and the influence of Saudi Vision 2030 by comparing the pre- and post-Vision periods. The results demonstrate that emphasizing blue indicators can substantially support sustainable growth and economic diversification, highlighting their critical role in shaping policy and investment strategies. The study provides valuable guidance for policymakers to refine Vision 2030 initiatives through targeted actions and investments, paving the way for a more sustainable and diversified economic future for Saudi Arabia.

The global shift toward renewable energy has fueled significant research on its impact on economic growth and environmental sustainability. Table 1 provides an overview of key studies exploring the influence of renewable and non-renewable energy, economic diversification, and policy frameworks on economic and environmental outcomes. These studies cover a range of geographic regions, including Kazakhstan, Africa, and Saudi Arabia, offering valuable perspectives on the interplay between energy consumption, innovation, and sustainability.

Table 1
Summary of related works

Reference	Aim	Methodology	Variables	Findings	Shortcomings
Raihan and Tuspekova (2022)	The study investigates the impact of economic growth, fossil fuel consumption, renewable energy adoption, and technological innovation on CO_2 emissions in Kazakhstan.	DOLS, FMOLS, and CCR.	GDP per capita, fossil fuel use, renewable energy use, technological innovation, CO_2 emissions.	Economic growth and fossil fuel use increase CO_2 emissions; renewable energy and technological innovation reduce emissions. Renewable energy has the most significant impact on sustainability.	Excludes recent data and developments in Kazakhstan. Focuses solely on CO_2 emissions, neglecting other environmental factors like water or land degradation. Does not delve into socio-political and economic barriers to renewable energy adoption.
Qudrat-Ullah and Nevo (2021)	To analyze the connection between renewable energy adoption, environmental sustainability, and economic growth across 37 African countries.	GMM.	Renewable energy consumption, CO_2 emissions, GDP.	Renewable energy positively influences economic growth, but environmental sustainability (CO_2 emissions) does not significantly impact growth. Renewable energy policies in Africa operate independently of sustainability considerations.	Limited to data from 2008 to 2014, excluding recent advancements. Focuses on CO_2 emissions as the sole measure of environmental sustainability. Lacks consideration of socio-political and economic factors.
Waheed et al. (2020)	To explore how economic diversification through non-oil exports, tourism, and renewable energy contributes to reducing Saudi Arabia's dependence on oil and promoting sustainable growth.	ARDL.	Non-oil exports, tourism, renewable energy, GDP.	Non-oil exports and tourism significantly boost economic growth. Renewable energy has a long-term positive impact but limited short-term influence due to high costs and infrastructure challenges.	Data limited to 1980-2017, excluding recent developments. Focuses on GDP as a sole sustainability measure, overlooking environmental and social dimensions. Lacks comparative perspective with other GCC nations and underdevelops discussion on renewable energy transition challenges.
Kahia et al. (2021)	To examine the interconnected relationships between renewable energy consumption, economic growth, and environmental quality in Saudi Arabia.	Simultaneous equation modeling.	Renewable energy consumption, economic growth (GDP), CO_2 emissions.	Economic growth drives energy consumption and CO_2 emissions, supporting the conservation hypothesis. Renewable energy aids in emissions reduction but has a limited impact. EKC hypothesis is validated only for liquid fuel emissions.	Dataset limited to 1990-2016, excluding recent policies and advancements. Focuses on CO_2 emissions, omitting other environmental metrics like biodiversity or water quality. Lacks exploration of barriers to renewable energy adoption.
Al Nemer	To investigate the relationship between renewable and non-renewable	Spectral Granger	Renewable energy, non-renewabl	Non-renewable energy supports economic growth in the short to medium term but	Does not address socio-political challenges or provide a comprehensive evaluation of

et al. (2023)	energy sources, CO_2 emissions, and GDP in Saudi Arabia.	causality method and wavelet analysis.	e energy, CO_2 emissions, GDP.	increases emissions. Renewable energy fosters economic growth and reduces emissions. Suggests transitioning to renewable energy for sustainability.	renewable energy adoption feasibility.
Waheed et al. (2023)	To assess the impact of blue factors (such as sea trade and tourism), energy, and green indicators on sustainable economic growth in Saudi Arabia, with a focus on the effects of Vision 2030.	Pre- and post-Vision 2030 analysis.	Blue factors (sea trade, tourism), energy indicators, green indicators, GDP.	Blue factors, particularly sea trade and tourism, significantly contribute to sustainable growth. Provides insights for refining Vision 2030 policies.	Limited to blue factors and Vision 2030 impacts without broader comparative analyses. Does not explore implementation challenges or socio-economic implications in detail.

Literature Analysis

Existing studies, such as those by Raihan and Tuspekova (2022), Qudrat-Ullah and Nevo (2021), and Waheed et al. (2020), have extensively examined the relationship between renewable energy, economic growth, and environmental sustainability. However, several gaps persist in the literature. Many studies rely on outdated data that fail to capture recent advancements and policy developments, such as Saudi Arabia's Vision 2030 initiatives aimed at transforming its energy landscape. Furthermore, much of the existing research narrowly focuses on CO_2 emissions as the sole measure of environmental sustainability, neglecting broader indicators like infrastructure development and technological advancements. Additionally, the critical role of government policies in moderating the impact of renewable energy adoption on economic growth remains underexplored. Finally, there is a lack of studies investigating how energy consumption patterns mediate the relationship between renewable energy strategies and sustainable economic outcomes.

Saudi Arabia, as a leading oil producer, faces the dual challenge of reducing its dependence on fossil fuels while fostering economic growth through sustainable practices. Despite progress under Vision 2030, the mechanisms through which renewable energy initiatives influence economic development, particularly the mediating role of energy consumption patterns and the moderating impact of government policies, are not sufficiently understood. This study addresses these gaps by applying Ecological Modernization Theory (EMT) to develop a comprehensive framework that explains the interplay of renewable energy projects, infrastructure, government support, and their collective impact on economic growth and sustainability.

Ecological Modernization Theory posits that economic growth and environmental sustainability can coexist, achieved through technological innovation, structural changes, and proactive government policies. The theory emphasizes the role of modernization and technological advancements in transforming economies toward sustainability without compromising development goals. This aligns with the proposed framework, which highlights renewable energy projects, technological advancements, and infrastructure as drivers of

modernization. Furthermore, the inclusion of energy consumption patterns as a mediating variable reflects how modernization shifts energy use from non-renewable to renewable sources, while government policy acts as a moderating variable, illustrating the enabling or constraining effects of institutional support.

By applying Ecological Modernization Theory, this study contributes to the literature by demonstrating how renewable energy strategies, supported by technological modernization and institutional policies, can drive sustainable economic growth in Saudi Arabia. The framework explicitly aligns with EMT principles, showing how modernization processes can align environmental and economic goals. This research provides actionable insights for policymakers, helping to design renewable energy policies and institutional frameworks that maximize economic and environmental benefits, ultimately advancing Saudi Arabia's transition to a sustainable future.

Theoretical Framework

Theoretical frameworks are essential for understanding the complex interplay of variables and their relationships in research studies. This section introduces a conceptual model designed to analyze the impact of renewable energy implementation on economic growth and sustainability within the Kingdom of Saudi Arabia. Rooted in Ecological Modernization Theory, the framework provides a structured approach to explore how renewable energy projects, supported by technological innovation and infrastructure development, can drive sustainable economic growth. It also examines the moderating role of government policies and the mediating effects of shifting energy consumption patterns. By integrating these elements, the framework offers a comprehensive lens through which to understand the economic transformation potential of renewable energy adoption in oil-dependent economies like Saudi Arabia.

For the proposed framework analyzing the impact of renewable energy on economic growth in Saudi Arabia, the variables can be defined as follows:

1. Independent Variable
- Renewable Energy Implementation: This includes the level of adoption and integration of renewable energy sources (solar, wind, geothermal) within Saudi Arabia. It encompasses factors such as the scale of renewable energy projects, installed capacity, technological advancements in renewable energy, and the presence of infrastructure supporting these energy sources.

2. Dependent Variable
- Economic Growth and Development: This represents the economic outcomes influenced by renewable energy adoption, including GDP growth, job creation, poverty reduction, investment levels, and overall economic stability in Saudi Arabia. It also considers improvements in energy security, reduced budget deficits, and reduced economic reliance on fossil fuel exports.

3. Moderating Variable
- Government Policy and Support: This variable moderates the relationship between renewable energy implementation and economic growth. Government policies, such as subsidies, incentives for renewable energy, regulatory frameworks, and public awareness campaigns, can strengthen or weaken the impact of renewable energy adoption on

economic growth. This variable represents the extent to which supportive or restrictive policies affect the success of renewable energy projects and their economic implications.

4. Mediating Variable

- Energy Consumption Patterns: This variable acts as a mediator between renewable energy adoption and economic growth. Changes in domestic energy consumption patterns—such as shifts from high fossil fuel consumption to increased renewable energy use—can influence economic outcomes. By reducing fossil fuel consumption for domestic needs, more resources can be allocated for export, potentially improving the trade balance and economic stability, thereby impacting economic growth indirectly through changes in energy consumption behavior.

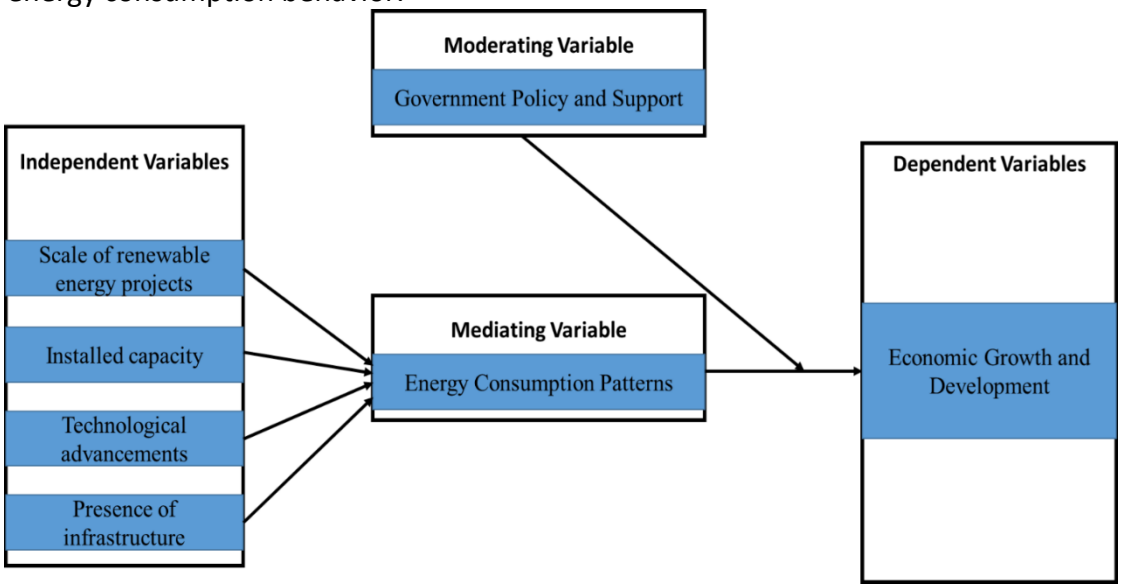

Figure 1. Conceptual model

The hypotheses in this study are designed to explore the intricate relationships between renewable energy implementation and economic growth in Saudi Arabia, with a focus on understanding the roles of government policy and energy consumption patterns as moderating and mediating variables. By examining these relationships, the hypotheses aim to uncover how the scale, capacity, technological advancements, and infrastructure of renewable energy projects influence energy consumption behaviors and, in turn, drive economic development. The framework is underpinned by the principles of Ecological Modernization Theory, which emphasizes the potential for technological innovation, sustainable energy practices, and supportive policies to align environmental sustainability with economic growth. These hypotheses collectively form the foundation for analyzing the transformative impact of renewable energy adoption on Saudi Arabia's economic landscape. The hypothesis of this study are as follows:

- **H_1**: The scale of renewable energy projects has a positive impact on energy consumption patterns.
- **H_2**: Installed capacity of renewable energy sources positively influences energy consumption patterns.
- **H_3**: Technological advancements in renewable energy positively affect energy consumption patterns.
- **H_4**: The presence of infrastructure for renewable energy positively impacts energy consumption patterns.

- **H_5**: Energy consumption patterns mediate the relationship between the scale of renewable energy projects and economic growth and development.
- **H_6**: Energy consumption patterns mediate the relationship between installed capacity and economic growth and development.
- **H_7**: Energy consumption patterns mediate the relationship between technological advancements and economic growth and development.
- **H_8**: Energy consumption patterns mediate the relationship between the presence of infrastructure and economic growth and development.
- **H_9**: Government policy and support moderate the relationship between energy consumption patterns and economic growth and development.
- **H_{10}**: Government policy and support strengthen the positive effect of renewable energy project scale on economic growth and development through energy consumption patterns.
- **H_{11}**: Government policy and support strengthen the positive impact of installed capacity on economic growth and development through energy consumption patterns.
- **H_{12}**: Government policy and support strengthen the positive impact of technological advancements on economic growth and development through energy consumption patterns.
- **H_{13}**: Government policy and support strengthen the positive impact of infrastructure presence on economic growth and development through energy consumption patterns.

The theory that most vividly proposes the proposed framework is Ecological Modernization Theory. EMT provides a conceptual resource for reading alignment opportunities between economic growth and environmental sustainability within technological innovation, along with supportive policies in general and around renewable energy in particular. How this may be supported through EMT is as follows:

- Renewable Energy as a Driver of Sustainable Growth:

EMT believes that economic development need not be on the cost of the environment, and at the same time invention of technology can spur non-polluting economic development. This is in line with the framework of renewable energy implementation as a driver for economic growth in Saudi Arabia. In this regard, the country will lower its dependence on fossil fuel by eventually integrating solar, wind and geothermal resources which will be ecologically as well as economically beneficial to the country.

- Role of Governmental Policy: Modernization of Energy Systems:

EMT stresses the lack of regulatory frameworks, incentives, and government support to develop workable economic models. In this framework, Government Policy and Support is a moderator variable that strengthens the positive relationship between the adoption of renewable energy and economic growth. Subsidies, incentives, regulatory policies, amongst others, create an enabling environment in which projects on renewable energy are economically viable, hence attracting private investment.

- Energy use shifts towards sustainability:

EMT also suggests the need for shifting consumption patterns to methods that are sustainable. In the model, Energy Consumption Patterns act as a mediating variable to explain how the adoption of renewable energy can translate into economic gains. In that, with the renewable energy sources accounting for an increasing percentage of domestic energy

consumption, more fossil fuel resources are available for export, translating into resultant economic gains without further environmental costs. The transition will be consistent with the logic Behind EMT, as it would be possible to comply not only with economic but also with environmental objectives by means of changing consumption and production practices.

- Technological and Structural Change and Economic Growth:

EMT supports the fact that economies achieve growth by shifting towards an unsustainable technology side from the traditional resource-based systems. This sets an overview of how, with such a shift, H4 and H5 hypothesize renewable energy projects can help in the generation of new job opportunities, reduction in poverty, and shortage of fossil fuel supplies because the economic resilience of Saudi Arabia is gained through this particular aspect.

Fundamentally, the Ecological Modernization Theory forms the backbone by substantiating the fact that with the innovation of renewable energy, governmental support, and shifting trends of energy consumption, it attains sustainable economic growth, a fact central to the study of the impact of renewable energy upon the economy of Saudi Arabia. The framework integrates several key variables to operationalize EMT. Independent variables include the scale of renewable energy projects, measured by the number and capacity of completed and ongoing initiatives; installed capacity, quantified in megawatts (MW); technological advancements, assessed through innovation indices and renewable energy patents; and the presence of infrastructure, evaluated by the availability of facilities supporting renewable energy adoption. Energy consumption patterns, serving as the mediating variable, are measured as the ratio of renewable to non-renewable energy use. Government policy and support, acting as the moderating variable, are assessed through policy indices, subsidies, incentives, and strategic frameworks like Vision 2030. The dependent variable, economic growth and development, is measured through GDP growth, employment creation in the renewable energy sector, and sectoral diversification.

The methodology employs a mixed-methods approach to validate the framework. Quantitative analysis, such as Structural Equation Modeling (SEM), is used to test relationships among variables and evaluate the mediating and moderating effects. Time-series data analysis captures the long-term impact of renewable energy on economic growth and sustainability. Complementing this, qualitative analysis involves policy reviews and stakeholder interviews to provide context to the quantitative findings. Data sources include global databases like IRENA and World Bank, as well as national statistics and reports on Vision 2030 implementation.

The relationships between variables are critical to understanding the dynamics of renewable energy adoption. Independent variables such as renewable energy projects, infrastructure, and technological advancements influence economic growth indirectly through shifts in energy consumption patterns. Government policies moderate these relationships by either enhancing or constraining the transition from non-renewable to renewable energy sources, ultimately affecting economic outcomes.

Conclusion

This paper underscores the critical role of renewable energy in driving economic growth and sustainability, particularly within the Saudi Arabian context. It highlights the environmental and economic limitations of continued reliance on fossil fuels and emphasizes the transformative potential of renewable energy strategies. Drawing on Saudi Arabia's Vision 2030, the paper identifies renewable energy as a cornerstone for economic diversification, job creation, and environmental preservation. The theoretical framework, grounded in Ecological Modernization Theory, positions renewable energy adoption as a driver of sustainable economic development through technological innovation, infrastructure improvements, and shifts in energy consumption patterns. The moderating role of government policies and the mediating effects of energy consumption transitions are key elements influencing the relationship between renewable energy initiatives and economic growth.

While existing studies provide valuable insights into the interplay between renewable energy, economic growth, and environmental sustainability, significant gaps remain, particularly in understanding the long-term impacts of policy frameworks and technological advancements. This paper contributes to bridging these gaps by proposing a comprehensive framework that integrates economic, social, and environmental dimensions. Future research should expand on this foundation by conducting empirical analyses of Saudi Arabia's renewable energy policies and their economic impacts, alongside exploring emerging technologies and their scalability within the region. This will provide actionable insights for policymakers and stakeholders, enabling the Kingdom to strengthen its position as a global leader in sustainable energy and economic development.

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