

IDENTIFYING AND ANALYZING THE ELEMENTS THAT FOSTER THE ADOPTION AND GROWTH OF RENEWABLE ENERGY

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ABSTRACT

Environmental concerns, especially the reliance on fossil fuels that fuel climate change and energy insecurity, are driving the global transition to renewable energy. Reducing carbon dioxide emissions and ensuring a steady supply of energy depend on the production of renewable energy. Therefore, a successful transition to a sustainable energy system depends on an understanding of the major elements impacting the production of renewable energy. This viewpoint emphasizes how crucial it is to pinpoint and examine the factors that encourage the uptake and expansion of renewable energy as a means of addressing issues related to the environment and energy security. This study uses data from 1995 to 2025 and is based on a time series analysis for Pakistan. Renewable energy generation is positively impacted by economic factors like GDP per capita and trade openness, as well as demographic aspects like urban population, environmental factors like ecological footprints, and political elements like governance. Environmental and energy-related factors have opposing effects, whereas demographic and economic considerations encourage the rise of renewable energy production. Thus, a stable and ecologically sustainable energy future depends on giving renewable energy generation precedence over other energy sources.

Keywords: Renewable Energy, Growth, Parameters, Production

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INTRODUCTION

The urgent need to address climate change and achieve sustainable development goals has brought natural energy sources to the forefront of global energy policy and investment agendas. Renewable energy sources, such as photovoltaic energy, wind energy, hydropower, geothermal energy, and bioenergy, offer a sustainable alternative to fossil fuels by harnessing natural processes

that are replenished over time [1]. This transition is crucial for reducing greenhouse gas emissions, enhancing energy security, and promoting economic growth while minimizing environmental impacts. The scientific consensus on climate change underscores the necessity of accelerating the adoption of renewable energy. The IPCC warns that limiting the global temperature

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rise to less than 2 degrees Celsius above pre-industrial levels is essential to avoid irreversible environmental damage and to mitigate the effects of global warming on vulnerable ecosystems and communities. Renewable energy technologies are vital for achieving these ambitious climate targets by displacing fossil fuels and lowering carbon emissions in the energy sector [2]. Effective governance is key to unlocking the full potential of energy as a driver of sustainable growth. Governance encompasses the policies, regulations, institutions, and decision-making processes that influence the deployment, integration, and scaling of renewable energy technologies. Well-designed governance frameworks provide the stability, predictability, and incentives necessary to attract private sector investments, stimulate technological innovation, and create an enabling environment for renewable energy deployment. Governance mechanisms for renewable energy include various policy instruments aimed at promoting investment and market growth, such as feed-in tariffs, renewable energy standards, tax rebates, grants, and subsidies, all designed to reduce financial risks and enhance sustainability [3]. Transparent and accountable governance practices ensure that renewable energy production adhere to environmental standards, mitigate social impacts, and involve stakeholders in decision-making processes. International cooperation and agreements play a significant role in advancing renewable energy deployment on a global scale.

The Paris Agreement, established in 2015 under the UNFCCC, seeks to limit the global temperature increase to well below 2 degrees Celsius and to strive for a cap of 1.5 degrees Celsius above pre-industrial levels. By committing countries to nationally determined contributions (NDCs) and fostering a collaborative environment, the

agreement provides a framework for scaling up renewable energy investments and accelerating the transition to sustainable energy systems worldwide. Several key factors influence the production, adoption, and integration of renewable energy technologies across various geographical and socio-economic contexts. These factors include technological advancements, economic considerations, political and regulatory environments, societal acceptance, and environmental concerns, each shaping the renewable energy landscape in unique ways. Technological innovation is critical for driving the evolution and cost competitiveness of renewable energy technologies. Advances in solar photovoltaic cells, wind power systems, energy storage devices, and smart grid innovations have significantly enhanced the efficiency, reliability, and scalability of energy solutions [4].

Research and development investments are consistently lowering the costs of energy technologies, enhancing their competitiveness against conventional energy sources. Economic factors play a crucial role in the market implementation and adoption of these technologies. Financial mechanisms such as feed-in tariffs, power purchase agreements (PPAs), tax incentives, and renewable energy certificates are essential for attracting private investment and minimizing the financial risks associated with renewable energy production. The decreasing costs of renewable energy technologies, combined with economies of scale and technological advancements, have strengthened the economic rationale for investing in renewables and facilitated their integration into traditional energy markets [5, 6].

Political will and robust regulatory frameworks are vital for the deployment of renewable energy. National energy policies, renewable energy targets, and supportive regulatory environments provide the policy

certainty and long-term planning necessary to attract investments and stimulate market growth. Regulatory measures such as emissions trading schemes, carbon pricing mechanisms, and renewable energy standards incentivize investments in renewable energy and promote the transition to sustainable energy systems [7]. Public support and societal acceptance are critical for overcoming barriers to energy transition initiatives. Engaging communities, consulting stakeholders, and addressing local concerns related to visual impacts, land use, and biodiversity are essential for gaining social acceptance and ensuring the successful implementation of energy transition projects. Building trust, transparency, and inclusiveness in decision-making processes enhances public confidence in energy transition technologies, positioning them as viable alternatives to fossil fuels. Environmental sustainability is a significant driver for adopting energy transitions, particularly due to the lower water consumption associated with renewable sources compared to fossil fuels. However, the environmental impacts related to energy transition deployment—such as land use changes, habitat disruption, and effects on biodiversity—underscore the necessity for thorough environmental assessments and mitigation strategies to ensure sustainable outcomes.

Pakistan, with its growing population and increasing energy demand, faces substantial challenges in ensuring energy security while addressing sustainability and environmental concerns. The country heavily relies on fossil fuels, particularly natural gas and oil, contributing to energy scarcity, environmental degradation, and economic vulnerability to volatile global energy prices. Recently, Pakistan has increasingly explored energy transition sources to diversify its energy mix, reduce greenhouse gas emissions, and achieve sustainable

development goals. With abundant sunlight and wind resources, Pakistan has significant potential for solar and wind energy generation. The government has implemented various policies and initiatives to promote energy transition, including feed-in tariffs, net metering schemes, and incentives for private sector investment in energy projects [8]. Pakistan's transition to renewable energy is a crucial pathway for achieving sustainable development, addressing energy security challenges, and mitigating the impacts of climate change. This transition is essential for identifying opportunities and strategies to accelerate the adoption of energy transition technologies, ultimately contributing to a sustainable and resilient energy future for the country.

Social factors, along with economic and political influences, play an important role in the adoption of energy transition. Research in the U.S. indicates that greater involvement in environmental advocacy groups correlates with an increased adoption of green electricity policies. Another U.S. study finds that the presence of state-level environmental organizations can predict the number of energy transition policies a state is likely to enact. In Japan, research highlights the importance of social capital, indicating that cities with stronger community connections are more supportive of wind power projects. Additionally, a cross-national analysis reveals that a greater number of international NGOs in a country is associated with higher solar energy production. Finally, studies examining population metrics such as size and density in relation to energy transition deployment yield inconsistent findings. For example, research on energy transition policy adoption in developing nations and Japan's shift toward energy transition underscores a positive role of population factors, while other studies observe negative effects on solar energy production in various countries.

Although the factors considered by scholars for production and consumption may be similar, their implications can differ significantly. For instance, economies with higher GDPs may experience increased energy production and consumption, but energy security improves when funds are allocated to developing energy transition projects. In summary, current research has significantly enhanced our understanding of how economic, political, social, and demographic factors influence the deployment of energy transitions. Nevertheless, further investigation is needed to explore whether additional variables also affect the adoption of energy transition strategies [9-11]. According to OPSV, both local issues (such as air and water pollution) and global threats (like ozone depletion and climate change) play crucial roles in shaping public environmental concern. Ronald Inglehart, a leading proponent of the theory, argues that environmental concern is primarily driven by substantial objective problems. The OPSV theory is supported by empirical data, which shows that people are more likely to understand the risks connected with climate change if they have personally experienced extreme climate events like heatwaves or floods. Additionally, public environmental concern and pro-environmental actions are favorably correlated with indicators of national or regional climate change vulnerability [12]. According to the OPSV theory, people who are exposed to environmental concerns may develop a sense of urgency and become more environmentally conscious. Less climate-vulnerable nations would see the dangers as far and ethereal, which would lessen their motivation to use fewer fossil fuels and support renewable energy sources. In contrast, countries facing vulnerability to climate-related risks, such as severe weather events causing economic and social losses, are more likely to prioritize measures to

mitigate climate impacts and transition to renewable energy sources, which are essential for combating climate change.

Research Objectives included 1. Evaluate the effectiveness of Pakistan's current policies and regulatory frameworks governing energy transition, 2. Analyze the economic feasibility and financial mechanisms that influence the adoption of energy transition projects in Pakistan, 3. Investigate the environmental impact and sustainability considerations associated with energy transition deployment in Pakistan.

RESEARCH METHODOLOGY

Energy production, viewed as a supply-side factor, is treated as the dependent variable because it effectively reflects the level of renewable energy integration in each nation's energy portfolio. A comprehensive review of the existing literature shows that the supply-side penetration of renewable energy has been studied less frequently than demand-side factors. Demand-side measures, such as renewable energy certificates, may not accurately represent a country's installed capacity since renewable energy can be imported from other nations. It was stressed that assessing renewable energy deployment solely by its proportion of total installed capacity is insufficient, highlighting the need for carefully chosen dependent variables. Renewable energy production and installed capacity illustrate a country's energy and industrial policies, while consumption reflects the actual utilization of RE sources [13]. Key factors such as economic growth, trade openness, population growth, CO₂ emissions, ecological footprints, governance, and energy production from oil, coal, natural gas, and nuclear sources are essential for accelerating investment in renewable energy projects and enhancing the integration of green technologies. In econometric model, the dependent variable, represents energy transition production, while the independent variables include gross domestic product per

capita, trade openness, urban population, electricity production from natural gas, nuclear sources, coal, oil, carbon emissions, governance index, and ecological footprints. This study utilizes time series data for Pakistan from 1995 to 2025. We test the model for normality, highlighting the importance of selecting appropriate dependent variables. The histogram suggests normality and a consistent trend in the data. The goodness of fit and the normal distribution of the residuals are evaluated using the Jarque-Bera test. A probability value of JB greater than 0.05 indicates that the residuals are normally distributed [14-16].

DISCUSSION

The findings indicate a significant positive relationship between GDP per capita and renewable energy production. Specifically, a unit increase in GDP per capita corresponds to a modest rise of 0.013 units in renewable energy production. This suggests that while higher GDP per capita positively influences renewable energy production, the impact is minimal, indicating a potential shortfall in funding for these initiatives. Such a small effect implies that many nations may not be adequately prioritizing renewable energy development. To promote the growth of renewable energy production, increased effort and prioritization are essential. These findings align with studies.

Open trade channels

The trade openness significantly and positively impacts renewable energy production at a 5% significance level. Specifically, a unit increase in trade openness leads to a 0.208 unit increase in renewable energy production. This indicates that greater trade openness is beneficial for the development of renewable energy production. Open trade channels facilitate the transfer of knowledge and technology, allowing countries to access the necessary expertise to advance their renewable energy

initiatives [17]. This influx stimulates local economic activities and encourages domestic production of green technologies. Consequently, trade openness is a vital factor in accelerating the transition to clean and sustainable energy solutions. These findings support earlier studies emphasizing the importance of trade openness in the global pursuit of renewable energy development.

Population expansion

The findings demonstrate that urbanization has a positive and highly significant impact on renewable energy production, with a significance level of 0.8%. Specifically, a unit increase in the urban population results in a 2.81 unit increase in renewable energy production. This indicates that urbanization plays a crucial role in driving the growth of renewable energy production. As the urban population increases, energy demand rises, which can be met through the expansion of renewable energy infrastructure [18, 19]. The significant positive relationship suggests that cities, with their concentrated populations and economic activities, are pivotal in adopting and advancing renewable energy solutions.

Urbanization, as a demographic factor, also positively impacts renewable energy production. Providing financial incentives to urban populations for adopting renewable energy solutions can further increase demand for green energy. Additionally, there is a positive association between governance and ecological footprints with renewable energy production; thus, policymakers should establish and empower institutions dedicated to renewable energy. Clear mandates, transparency, and accountability are essential for effective governance. Integrating renewable energy solutions into urban planning and promoting the use of solar panels, wind turbines, and other renewable technologies in urban development projects is vital [20].

Non-renewable electricity production

The results indicate that electricity production from natural gas and oil significantly hinders renewable energy production at a 0.85% significance level. Specifically, a unit increase in electricity generation from natural gas leads to a 0.22 unit decline in renewable energy production, creating an obstacle for renewable energy development. Similarly, a unit increase in oil energy generation results in a 0.55 unit reduction in renewable energy production. The findings also show that coal electricity production negatively impacts renewable energy production; a unit increase in coal electricity generation reduces renewable energy production by 3.2 units at a 8% significance level [21]. This analysis suggests that stakeholders invested in conventional energy sources pose a significant barrier to the growth of renewable energy production. Their concerns about potential revenue loss from non-renewable energy, coupled with powerful lobbying efforts to maintain fossil fuel usage, impede the progress of renewable energy initiatives. This prioritization of financial interests over environmental benefits delays the transition to a more sustainable, low-carbon economy. Significant energy production from oil, coal, natural gas, and nuclear sources hinders the progress of renewable energy production. When energy production from these sources is substantial, renewable energy production struggles to advance. Implementing supportive measures will drive economic growth, reduce CO₂ emissions, and enhance energy security by decreasing reliance on costly fossil fuels [22]. However, countries rich in mineral resources may resist renewable energy production due to concerns about losing revenue from these resources. While nuclear energy is environmentally friendly, its high costs and proliferation risks make it less favorable compared to renewable energy. Therefore, prioritizing renewable

energy production over other energy sources is essential for achieving a stable and environmentally sustainable energy future.

Carbon dioxide emissions

The results indicate that CO₂ emissions, as a measure of environmental degradation, have a significantly negative impact on renewable energy production at a 1% significance level. Specifically, a 1 unit increase in CO₂ emissions results in a 17.91 unit decrease in renewable energy production. This finding suggests that higher CO₂ emissions, stemming from increased electricity production from conventional energy sources, are linked to a reduction in the share of renewable energy production [23]. As conventional energy production rises and environmental pollution worsens, the proportion of renewable energy production tends to decline.

Ecological Footprints

Ecological footprints serve as a proxy for environmental vulnerability and show a significant positive relationship with renewable energy production. Specifically, a unit increase in ecological footprints corresponds to a 37.3 unit increase in renewable energy production at a 1% significance level. This positive correlation arises from several interconnected factors. High ecological footprints typically indicate greater energy demands, which drive investments in renewable energy to mitigate environmental impacts. Additionally, governments in countries with high ecological footprints may actively promote renewable energy initiatives to counteract environmental harm. Economic growth further supports this trend by providing the financial resources necessary for advancing renewable energy technologies. Consequently, the increase in renewable energy production reflects efforts to address and alleviate the environmental challenges associated with elevated ecological footprints.

Good governance

The governance index serves as a proxy for political factors and is constructed using five indicators: control of corruption, regulatory quality, rule of law, transparency, and accountability. The results show a positive association between governance and renewable energy production, with a 1 unit increase in governance leading to a 5.44-unit increase in renewable energy production at a 1% significance level [24]. Strong governance fosters a stable and predictable policy environment that attracts investments in renewable energy production, as noted by the International Renewable Energy Agency. Effective governance ensures the implementation of supportive regulations and incentives, such as tax credits, net metering laws, and renewable portfolio standards, which encourage the growth of renewable energy, as highlighted in the Renewable Energy Policy Network report.

CONCLUSION

In recent years, researchers have increasingly focused on boosting the share of renewable energy production in overall energy generation by leveraging factors that support the adoption of renewable energy. This study conducts a time series analysis of Pakistan from 1995 to 2025 to identify the key factors that enhance renewable energy production. The analysis reveals several determinants, including economic sustainability. Economic variables such as GDP per capita and trade openness, along with demographic factors like urban population, positively influence renewable energy production. In contrast, environmental proxies like CO₂ emissions and energy-specific variables—such as electricity production from oil, natural gas, and coal—negatively impact renewable energy production. Thus, while economic and demographic factors promote renewable energy production growth, environmental and energy-related variables exert opposing effects. To increase renewable energy

production, policymakers should prioritize economic growth and foster a supportive environment for businesses.

This economic growth will provide the necessary funding for green energy investments. However, it is crucial to prioritize renewable projects over traditional energy sources. Wealthier countries can invest in renewable energy but may not always prioritize it due to competing concerns. In developing countries, income inequality can hinder the adoption of renewable energy. Therefore, a balanced approach that considers both economic and environmental factors is essential for encouraging investments in renewable energy. The positive relationship between trade openness and renewable energy production indicates that expanding trade can facilitate the rapid and widespread adoption of green technology. Policymakers should view trade openness as a central factor in supporting renewable energy production. While wealthier nations may initially focus on business profits, both affluent and developing countries will benefit in the long term by reducing carbon emissions. Policymakers in developing nations must effectively communicate the importance of transitioning to green energy to their citizens.

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