Research on Long-Term Effects of Renewable Energy on Different Countries' Economic Growth and Optimization Strategy

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Abstract. Given the pressing need for sustainable development amidst climate change, the transition to renewable energy is critical for enhancing energy security and fostering economic resilience. This research examines the long-term effects of renewable energy on economic growth, with a focus on China as a pivotal case study. Although the development of renewable energy is beneficial to China in many aspects, such as the economy, trade balance, and employment, there are still several key problems in the process. High initial costs, technological and infrastructure limitations, global market fluctuation, and policies are the main focuses. To optimize the benefits of renewable energy, this study suggests establishing an initial economic support fund to facilitate the implementation of the policy, maintaining the current trend of increasing innovation investment and using diversified market strategies. Ultimately, the findings underscore the importance of renewable energy as a catalyst for sustainable economic growth, offering valuable insights for policymakers and stakeholders in China and beyond and highlighting the role of leadership in the global energy transition.

Keywords: Renewable Energy, Chinese Economic, Market Fluctuation, Technology Limitation.

1. Introduction

1.1 Research Background

In recent years, the demand and development of new energy sources have continued to accelerate globally, especially in the context of combating climate change and reducing dependence on fossil fuels. According to the International Energy Agency's (IEA) 2023 report, the world's new renewable power generation capacity increased by 50% to 507 gigawatts, a record high. Solar power accounted for two-thirds of the new capacity, with wind contributing the remaining quarter. These figures reflect the increasing importance of new energy sources in the global energy mix.

The definition of new energy includes renewable energy sources that can replace traditional fossil fuels, such as solar, wind, geothermal, and hydropower. These energy sources are not only clean and renewable but also have a far less negative impact on the environment than traditional energy sources. In 2023, the world has made significant progress in investment and policy support for clean energy, notably the rapid growth of solar and wind power in the United States through the Inflation Reduction Act (IRA) and the accelerated deployment of renewable energy in the European Union through energy security goals. Also, China is particularly strong in this area, accounting for 63% of the world's new solar capacity in 2023 and 65% of wind capacity, far more than any other country. As policy drives and technology advances, wind and solar will continue to lead the clean energy revolution in the coming years, with renewables expected to overtake coal as the largest source of electricity generation globally by 2025.

In the long run, the promotion of new energy will have a profound impact on the global economy. The IEA report states that by 2028, new energy sources will account for more than 42% of global electricity production. This trend will not only help to achieve climate goals but will also bring a large number of jobs and technological innovations, which will promote the upgrading of the global industrial structure. In addition, the widespread use of new energy sources will also significantly

reduce the cost of electricity, especially solar and wind power, in 2023, which has surpassed the price competitiveness of most fossil fuel power plants. Overall, the process of the global energy transition will accelerate in the coming years, bringing about major economic and social changes.

1.2 Literature Review

Pereira, Sequeira, and Cerqueira from the University of Coimbra have found that renewable energy positively influences economic growth in both developed and developing countries, but the extent of this effect varies based on the economic structure and energy policies of each country [1]. Alper and Oguz investigated the causality among economic growth, renewable energy consumption, capital, and labor for new EU member countries for the period of 1990–2009 by using the asymmetric causality test approach and autoregressive distributed lag (ARDL) approach. The empirical results supported that renewable energy consumption has positive impacts on economic growth for all investigated countries [2]. Alam, Ahmed, and Begum found that unidirectional causality runs from economic growth to energy demand, which indicated that conservative policy might not harm the Bangladesh economy, but since economic progress leads to higher energy consumption, demand side management of energy and exploring renewable energy sources are a must [3].

1.3 Research Gap

The existing research on the impact of new energy on economic development mainly focuses on several aspects. First of all, the relationship between new energy and economic growth has been widely discussed. It is generally believed that new energy consumption has a positive effect on GDP growth, especially in countries with strong policy support. In addition, the impact of the policy has received a lot of attention. Research shows that policy measures such as tax breaks and subsidies play a key role in promoting the application of new energy and driving economic growth. Technological progress is another important research theme that promotes the reduction of new energy costs and economic benefits, especially in the field of solar and wind technology innovation.

In contrast, there are still shortcomings in the existing research with regard to the heterogeneity of different countries, especially developing countries and emerging markets. There is little research on how the differences in policies, technologies, and resource endowments of these countries affect their new energy development and economic efficiency.

1.4 Research Framework

The rest of the study begins with an analysis that delves into the current state of renewable energy use, exploring and revealing the main issues and challenges that currently exist through data analysis and case studies. The second part is the suggestion part, based on the above analysis results, putting forward the solution and optimization suggestions for the problem. The last part is the conclusion, which summarizes the core findings and suggestions of the study, discusses the limitations of the study, and puts forward the direction for future research.

2. Analysis on the Problem

2.1 China: The Interaction between Renewable Energy Development and Economic Growth

China has promoted the development of renewable energy in the past few decades, especially in the fields of wind, solar, and hydropower. As the world's largest investor in renewable energy, China's renewable energy development has not only had a profound impact on the domestic economy but also provided an important reference case for the global energy transition.

2.1.1 Economic Impact

The development of renewable energy in China has greatly promoted the country's economic growth. By investing heavily in projects such as wind, solar, and hydropower, the government has not only promoted the rise of renewable energy-related industries but also created a lot of jobs.

According to the International Renewable Energy Agency (IRENA), China will account for 30% of global renewable energy investment in 2020, making it not only the largest renewable energy market in the world but also enabling several regions of the country to leapfrog economic development. Especially in remote areas, the construction of wind power and photovoltaic projects has led to the simultaneous development of local infrastructure construction, transportation, and manufacturing.

Renewable energy development has also fueled China's technological innovation and the rise of manufacturing. China is now the world's largest producer of photovoltaic modules, accounting for more than 70% of global output. This has not only driven the development of domestic manufacturing but also promoted the increase of foreign exchange earnings through the export of photovoltaic products. Taking the photovoltaic industry as an example, technological improvements and large-scale production of photovoltaic panels, inverters, and power storage equipment have significantly reduced the cost of photovoltaic power generation and further enhanced market competitiveness. In addition, with the rapid development of renewable energy in China, energy independence has also increased. Reducing dependence on imported fossil fuels not only reduces the energy trade deficit but also enhances national economic security. In times of global energy market volatility, China has reduced its sensitivity to international market price changes through its homegrown renewable energy supply.

2.1.2 Improvement in the Trade Balance

By expanding the use of renewable energy, China has improved its trade balance to some extent. First, by reducing imports of oil and coal, China's total imports have fallen. For example, in 2020, lower oil prices due to the global coronavirus pandemic and the expansion of renewable energy helped China reduce the cost of imported energy. According to China's General Administration of Customs, China's crude oil imports fell 26 percent in 2020, and coal imports fell 17 percent. Second, China has significantly improved its trade balance through the export of renewable energy technologies. China is not only the world's largest manufacturer of photovoltaic modules but also a major exporter of solar equipment. According to the International Renewable Energy Agency, China accounted for nearly 70% of global PV module exports in 2021. These exports generate significant foreign exchange earnings, further improving China's trade balance.

In 2021, China's total PV module exports reached $28.5 billion, with major export markets including Europe, Southeast Asia and North America. The export growth of photovoltaic modules has not only boosted manufacturing but also boosted exports of equipment, technologies, and services related to clean energy, enhancing China's competitiveness in the global energy market. In addition, with the promotion of the Belt and Road Initiative, China has exported a large amount of renewable energy technology and equipment to countries along the route, further promoting trade expansion.

2.1.3 Employment

The development of the renewable energy industry has created a large number of jobs in China. According to the China Renewable Energy Association, the number of people employed in China's renewable energy sector has exceeded 5 million by 2021. Renewable energy development not only provides a large number of jobs for skilled workers but also promotes employment growth in related industrial chains, including manufacturing, installation, maintenance, and research and development. Professor Ibrahim believed that the development of renewable energy would result in employment and economic benefits, many times the R&D investment [4].

For example, the development of the photovoltaic industry has greatly boosted the demand for talent in fields such as semiconductors, electrical engineering, and materials science. The wind power industry has also led to the transformation of traditional industries such as machinery manufacturing and civil engineering. Compared with traditional energy industries, the clean energy industry relies more on highly skilled labor, which improves the quality of the overall labor market to some extent.

In addition, the construction of wind power and photovoltaic projects in rural areas has increased local employment opportunities, improved residents' income levels, and reduced poverty rates. In

Gansu and Ningxia, for example, the construction of multiple solar power stations has provided installation and maintenance jobs for local farmers, greatly improving living conditions.

2.2 Problem Identified Analysis

Although China has made great achievements in the development of renewable energy, there are still several key problems in the process.

2.2.1 High initial costs and funding challenges

A major obstacle to renewable energy development is high initial costs. Although the cost of PV and wind technology has decreased significantly over the past decade, the capital requirements for initial installation and infrastructure construction remain large. In particular, large-scale wind farms and solar power plants require a large amount of capital investment for construction and maintenance. For example, wind power projects in places such as Inner Mongolia and Xinjiang, while rich in wind energy resources, are far from major consumer markets, resulting in high construction and transmission costs.

Although the Chinese government has provided extensive policy support for renewable energy, such as subsidies and low-interest loans, with the gradual tightening of policies and the reduction of subsidies, companies need more self-financing to keep projects running. In addition, with the increased uncertainty of international investors about the Chinese market, the source of external funds has also been restricted, which has made some small and medium-sized renewable energy companies face great pressure in financing.

2.2.2 Intermittency and grid integration issues

Intermittency is a significant challenge for the development of renewable energy in China. The amount of electricity generated by wind and solar is dependent on natural conditions, which leads to fluctuations in energy supply. As China develops large-scale renewable energy projects, especially wind and photovoltaic power generation projects in northwest and North China, it faces the challenge of effectively integrating these intermittent energy sources into the grid.

In provinces with a high proportion of wind power and solar power generation, such as Gansu and Qinghai, there has been a phenomenon of “abandoning wind and abandoning light”. Due to insufficient grid infrastructure, it is not able to fully absorb the renewable energy generated during peak hours, resulting in some power generation being forced to waste. At night or when there is no wind, the power supply can be insufficient, forcing grid companies to use thermal power as a supplement. This situation not only affects the economics of renewable energy but also affects the stability of the grid.

In response, China has invested heavily in the modernization of its power grid in recent years, especially in the promotion of “UHV transmission” technology to enable large-scale cross-regional transmission. However, the construction of these technologies and infrastructure still takes time, and it is difficult to fully solve the intermittency and grid-connection problems in the short term.

2.2.3 Policy and regulatory barriers

Although China’s policy support for promoting renewable energy development is strong, there are still some policy and regulatory obstacles. For example, despite many policies to support renewable energy at the national level, there is slow progress and insufficient coordination in the implementation of policies by local governments. Sometimes, local governments prefer to develop traditional energy sources, especially due to the greater economic interests of the coal industry, which has hindered the approval and development of renewable energy projects.

In addition, China’s power grid system has long been dominated by large state-owned enterprises such as State Grid and Southern Power Grid, and private companies face high barriers to entry and regulatory restrictions when entering the power market. Traditional power companies have also resisted the spread of distributed photovoltaic power generation in some regions because distributed generation can weaken the revenue source of grid companies. How to promote the development of

distributed energy without affecting the profitability of grid companies is a major challenge for current policy and regulation.

2.3 Reason Analysis of Problem

2.3.1 Conflicts of interest between local and central authorities

The central government usually sets macro policies that emphasize sustainable development, environmental protection, and long-term economic benefits, while local governments tend to focus more on short-term economic growth and fiscal revenue. In some places, especially those whose economies depend on traditional energy sources such as coal and oil, the implementation of new energy policies may weaken the competitiveness of traditional industries, leading to fewer jobs and lower local fiscal revenues.

For example, in some coal-producing areas, the local economy is highly dependent on coal mining and related industries, and although the central government has promoted policies to reduce carbon emissions and develop clean energy, local governments may be reluctant to significantly reduce coal mining because it will directly affect local tax revenue and employment. As a result, local governments may discount or delay the implementation of central policies.

2.3.2 Technological and infrastructure limitations

Although China has made significant progress in renewable energy technology, insufficient energy storage technology, backward grid infrastructure, lagging construction of smart grids, and insufficient technological innovation capacity remain major obstacles to the large-scale promotion of renewable energy in the future.

According to the International Energy Agency (IEA), by the end of 2020, China's grid will have only 3.3 GWH of installed energy storage capacity, compared to 24.6 GWH in the United States [5]. Although China is one of the world's largest markets for wind and solar power, the development of energy storage technology has lagged far behind the growth of power generation capacity.

China's installed wind power capacity will reach 281 GW in 2020, while the installed photovoltaic capacity will reach 253 GW, and the lack of energy storage facilities makes a large amount of power at the peak of production "abandoned wind and light." For example, in regions rich in wind and solar energy resources, such as Gansu and Inner Mongolia, due to insufficient energy storage capacity and imperfect grid infrastructure, there is excess power generation capacity at peak times, which cannot be absorbed in time.

Research conducted by Pilz and AL-Fagih shows that one reason for investors not to finance an RE project is grid non-availability, which means the grid infrastructure cannot accommodate the additional power when there is electricity production [6]. According to the data of the China Electricity Council, less than 30% of China's power grid was intelligently upgraded in 2020, far lower than that of internationally advanced countries such as Germany and Japan. With the development of distributed energy, microgrids, and energy storage systems, the construction of smart grids will be more urgent.

The further development of China's new energy is faced with the problem of insufficient innovation capacity and insufficient investment in research and development.

According to the statistics of the World Intellectual Property Organization (WIPO), although the number of patent applications in China in the field of renewable energy technology has increased significantly in recent years, the degree of innovation and breakthrough of the technology is still relatively low. In 2020, China's R&D investment in renewable energy will only account for 0.8 percent of GDP, compared with 1.2 percent and 1.5 percent for technology leaders such as Germany and the United States.

2.3.3 Global market fluctuations and resource allocation

Finally, global market volatility has also had a profound impact on the development of renewable energy in China. Although China is the world's largest producer of photovoltaic modules, the prosperity of this industry also depends on international market demand and price stability. Price

fluctuations in raw materials for PV modules, such as silicon wafers and glass, as well as disruptions in global supply chains, could negatively impact China's renewable energy development.

For example, during the Sino-US trade war in 2018, the export of photovoltaic modules was affected by tariffs, resulting in a setback for the export of China's photovoltaic industry. In the future, similar international trade frictions could affect China's competitive position in the global renewable energy market.

3. Suggestions

3.1 Conflicts of Interest between Local and Central Authorities

From 2007 to 2019, the Chinese government greatly subsidized the new energy vehicle industry, which gave China the highest sales of new energy vehicles all around the world in 2015. This is enough to show that the size of government subsidies has greatly affected the market supply and demand and the development of related industries. In this situation where there are conflicts of interest between local and central governments if the central government can provide economic subsidies to local governments at the initial stage of the development of new energy projects, it will greatly ease the economic pressure on local governments and make local governments more willing to develop new energy. The question here is what kind of subsidy policy the government should make.

Zhao's study in 2016 found that China has preferential tax policies in VAT, income tax, and import duty for the REPG industry, and strong financial subsidies have also been provided to support wind power and solar PV power projects. By contrast, explicit fiscal and tax incentive policies for geothermal power have not yet been issued [7]. The study Wu Wanshan, Li Xi, Lu Zhou, Gozgor Giray, and Wu Keke did in 2022 noted that an increase in energy subsidies on a per capita basis would have a negative impact on carbon efficiency. However, green growth-oriented local energy subsidies for clean energy and low-carbon industries can help to improve carbon efficiency [8]. Thus, the local economy can find a balance between economic growth and carbon emission reduction. Therefore, policymakers should adjust the existing performance evaluation mechanism with economic growth as the core and promote local governments to implement green growth and low-carbon economic development policies.

3.2 Technological and Infrastructure Limitations

3.2.1 Energy storage technology

The energy storage industry is highly price-sensitive. At present, China's new energy storage market has not yet formed a stable income model with a low-profit level, and difficulty in forming a reasonable cost dredging mechanism is a problem plaguing the development of new energy storage.

Chen Haisheng said that for energy storage to enter the power system, it is necessary to establish a more reasonable price mechanism and market environment. "We should measure the value of energy storage from a global perspective, uphold the principle of 'who benefits, who bears', and establish a reasonable energy storage price mechanism that is shared by power generation, the grid, and users. Yu Huigen, chairman of Beijing Weilan New Energy Technology Co., LTD., believes that it is necessary to improve the performance and quality of energy storage products and establish and improve graded, quantified national standards and industry standards as soon as possible [9].

3.2.2 Underinvestment in research and development

According to the report published by IEA in 2022, although there was virtually no energy R&D activity in China prior to 2000, Chinese actors (public research institutions, universities, state-owned enterprises, and private enterprises, including start-ups) have steadily increased their share of the world's new energy technology development [10]. Today, China leads the world in public spending on energy research and development and is second only to the US in spending on low-carbon energy research and development. In specific technology areas such as solar photovoltaics, recent patent

filings, and performance trends suggest that China may already be on par with other leading innovation nations.

China's future new energy development needs to maintain the current trend of increasing innovation investment year by year.

3.3 Global Market Fluctuations and Resource Allocation

The government should promote a diversified energy mix by investing in a variety of renewable sources, including solar, wind, hydro, and geothermal energy. This approach can mitigate risks associated with reliance on specific resources and help stabilize the energy supply against international price volatility.

Fostering international partnerships is crucial. China can strengthen its involvement in global renewable energy initiatives by collaborating with countries that have advanced technologies and best practices. These partnerships can enhance innovation and facilitate technology transfer, ultimately improving the efficiency and effectiveness of renewable energy projects.

4. Conclusion

4.1 Key Findings

This research highlights the dynamic relationship between renewable energy development and economic growth in China, identifying key areas of impact such as economic benefits, trade balance improvement, and job creation. However, challenges related to funding, intermittency, policy barriers, technology limitations, and global market fluctuations remain significant obstacles. Addressing these issues through targeted strategies will foster a more sustainable and resilient energy landscape.

4.2 Research Significance

The findings underscore the social value of advancing renewable energy in promoting sustainable development and addressing climate challenges. This study contributes to understanding the multifaceted impacts of renewable energy and provides actionable insights for policymakers.

As a leading country in the development of new energy, China faces obstacles on the road to development, and the methods that should be used to overcome them and further maintain development advantages are the core of this paper.

4.3 Limitations

There are still many limitations in this research, the most obvious one being the lack of primary data, which may lead to the inability to capture the full scope of local challenges and opportunities. Future studies should incorporate primary data through surveys or interviews to deepen insights and validate findings, enhancing the overall understanding of renewable energy's role in economic growth.

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