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Impact of Renewable Energy Consumption on the Economic Growth: A Comparative Analysis between India and the USA

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Abstract

Non-renewable sources of energy like coal, petroleum, and gas have helped in the economic growth of a country immensely but they have certain social, economic, and environmental disadvantages, thus encouraging us to use more environment-friendly renewable sources of energy. These renewable energy sources eliminate harmful gasses like carbon monoxide, excess carbon dioxide, etc. Moreover, they can be used for power generation, which can further generate energy. The study aims to conduct a comparative study of the relationship between energy consumption from renewable sources and economic growth in India and the United States of America. The study uses secondary data from the period 1990-to 2018. We have taken the renewable energy consumption and GDP per capita data from the World Bank site for this research. The statistical analysis is based on descriptive statistics, regression analysis, and correlation using Microsoft Excel. The results show that there is a positive correlation between renewable energy consumption and the economic growth of the USA whereas there is a negative relationship between economic growth and renewable energy consumption in India.

Keywords: *renewable energy, consumption, economic growth, India, United States of America*

1.0 Introduction

Many countries have achieved economic growth during the past few centuries due to industrialization. The process of industrialization is primarily the period of social and economic change that transforms a human group from an agrarian society into an industrial society. This involves an extensive re-organization of an economy for manufacturing [1]. Industrialization comes at a heavy cost of the depletion of the non-renewable sources of energy like coal, petroleum, etc, and the emission of greenhouse gases like carbon dioxide, methane, and carbon monoxide leading to global warming and climate change. International attention to global warming and climate change has led to a concerted global effort in reducing carbon emissions. Efforts were initiated to reduce the share of fossil fuel-driven emissions in the Kyoto Protocol, 1997. The treaty compelled the industrialized countries to reduce greenhouse gas emissions, particularly CO2. Consequently, many developed and emerging countries started to shift from dependence on fossil fuels to renewable energy [2]. However, if emission reduction pledges at the current level, the world's temperature will

increase to almost twice the limit referred to in the Paris Agreement by the end of the century [3]. Therefore, the need to shift from non-renewable to renewable sources of energy and to find a sustainable solution for energy challenges has become even more critical.

The critical question is whether the consumption and production of renewable energy will contribute to economic growth. However, there is some discrepancy in the relationship between whether there will be economic growth with increased consumption of renewable energy. The differences in the theoretical propositions could be summed up in four different hypotheses. First, the energy conservation policies and increased consumption of renewable energy may adversely affect economic growth. It is argued that economic growth is largely dependent on traditional energy sources. This proposition is called the growth hypothesis. The second, the "conservation hypothesis," proposes that energy-saving policies may be adopted with little or no negative impact on economic growth. The "growth hypothesis" implies that energy consumption is vital for economic growth. The "feedback hypothesis" is the final one that involves bidirectional causality between the two elements. An investigation of the above hypothesis can be used to develop an energy policy. Energy conservation policy entails reducing energy consumption in order to stimulate economic growth. [3]. We intend to analyze whether this hypothesis should be accepted or rejected. Given the importance of renewable energy, it is important to determine a relationship between renewable energy consumption and economic growth. No such previous study was done on the United States of America and India. This paper aims to address the same in the context of India and the United States of America where India has been taken as the representative of a developing country and the United States has been taken as the representative of a developed country.

2.0 Review of Literature

For the period 1980–2011, data analysis was conducted on OECD nations. Their research uncovers a long-term link between energy use (both renewable and conventional) and industrial production and economic growth [4]. In the short run, there was also evidence of a two-way relationship between conventional energy consumption and GDP growth. According to these findings, expanding renewable energy sources is a realistic approach for addressing energy security and climate change, while gradually replacing fossil fuels with

renewable energy sources promotes a sustainable energy economy. An investigation was conducted on the influence of REC on economic growth in China by estimating Cobb–Douglas production functions for the years 1978 to 2008, concluding that REC has a positive impact on GDP. Using the multivariate ordinary least squares method, it was discovered that a 1% rise in REC boosts real GDP by 0.12%[5]. There was a study on the economic growth impacts of renewable and non-renewable energy in Europe and Eurasian countries. The findings reveal that, whereas the growth rate of non-REC has a negative influence on GDP growth, the growth rate of REC has a favourable impact [6]. Data from 80 nations were used to create a statistical model in which GDP is the dependent variable and power consumption from renewable and conventional sources, as well as various macroeconomic variables, are the key explanatory variables. The findings demonstrate a two-way link between RES use, conventional energy, and GDP in both the short and long run. There is also a two-way short-run relationship between renewable and non-renewable energy sources, implying that switching between energy sources is possible [7]. A study in 2018 was conducted to investigate whether there is a link between REC and economic growth in European countries. The results show that nations with greater GDP have a higher correlation between the two variables than countries with lower GDP [2].

A large number of studies have been conducted on the relationship between renewable energy and economic growth but they have certain limitations. They lack uniformity in determining the relationship with the existing data. Different studies support different hypotheses. A very limited number of studies have been conducted on the changed share of renewable energy consumption to the total energy consumption and their impact on economic growth. Further, no empirical study has been conducted to derive a comparative analysis between India and the USA determining the impact of renewable energy consumption on the economic growth of the respective nation.

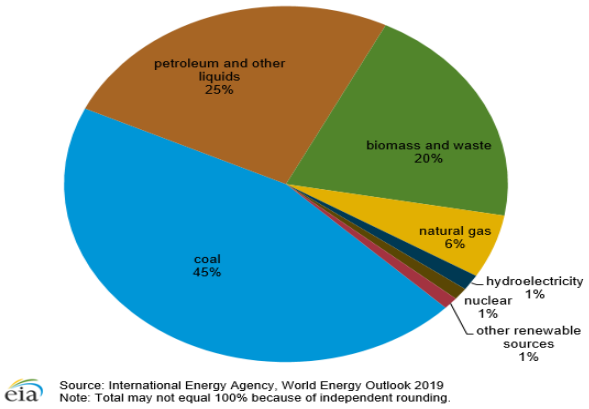
3.0 Trends in the Usage of Renewable Energy in India and the United States of America

The data in Table A1 and A2 gives the share of renewable energy consumption (REC) out of the total consumption in India and the United States of America from 1990 to 2018. It shows that the share of renewable energy consumption to total energy consumption has reduced in India over the period whereas it has increased in the United States.

Between 1990 and 2018, India's primary energy consumption nearly tripled, reaching an estimated 916 million tonnes of oil equivalent [8]. In 2018, coal continues to provide the majority (45%) of India's overall energy consumption, followed by petroleum and other liquids (26%), and traditional biomass and waste (20%). Other renewable fuel sources provide for a modest fraction of primary energy consumption, even though several of these resources, such as solar, wind, and hydroelectricity, have enormous capacity potential. Over the last few years, the country has shifted away from traditional biomass and garbage as the availability of electricity connections for the household and commercial sectors has increased. Even though natural gas accounts for only 6% of India's total energy consumption, the country intends to expand its natural gas market share to 15% by 2030 as part of the country's plan to reduce air pollution and use cleaner-burning fuels [9].

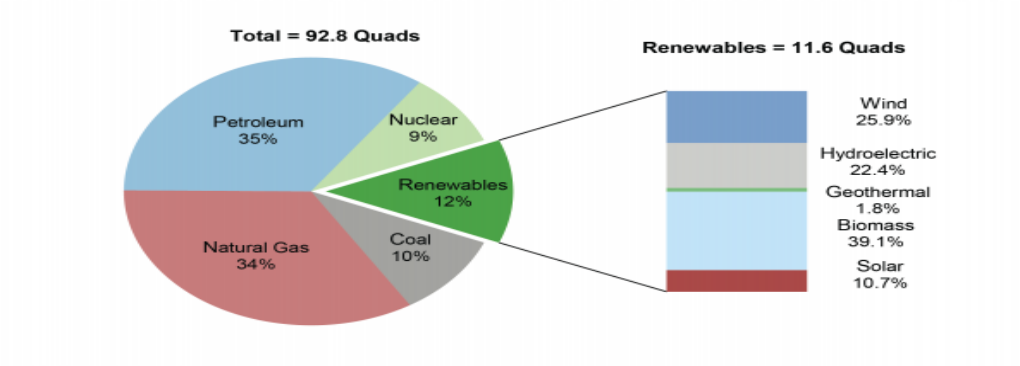
Figure 1

Figure 1. India total primary energy consumption by fuel type, 2019



Fossil fuels account for 78% of the USA's energy, nuclear account for 8.9%, and renewables account for 12.5%. Renewables surpassed coal as the source of energy in the United States in 2019, and this trend is expected to continue in 2020. Although wind and solar are the fastest-growing renewable energy sources, they only account for 4.6% of total renewable energy production.

Figure 2: U.S. Total and Renewable Energy Consumption by Source, 2020



Source: U.S. Energy Information Administration (EIA) (2021) Monthly Energy Review May 2021

Over the years, the government policies favouring the renewable sector of India and the USA have made progress in the total volume of consumption but its share in the total energy consumption is decreasing in India but increasing in the USA. This raises the question of whether recent economic development in these economies is being fuelled by the increased use of fossil fuels.

4.0 Methodology

This paper considers sustainable energy as the measure of the share of renewable energy consumption in total energy consumption per capita unit. Economic growth is assessed by GDP per capita because the study's goal is to see how GDP per capita affects economic growth. The study is based on annual data on GDP and Renewable energy consumption that are collected from 1990 to 2018 for India and the USA. These two countries are selected for study since existing literature lacks comparative study on this subject in the aforementioned countries. The required data are collected from World Bank's database, i.e., World Development Indicators.

To analyze the impact of sustainable energy on economic growth, the following model has been estimated as:

$$GDP = f(REC) \quad \ldots\ldots(1)$$

In this model, GDP is per capita GDP, REC is the share of REC in total energy consumption, and since the study involves two countries and the impact of sustainable energy on economic growth in these countries had to be investigated, in the first stage, a simple linear regression

model has been estimated. The equation has been stated as follows:

$$Y = \beta_{1i} + \beta_2 X_{2i} + \epsilon_i \quad \text{.....(2)}$$

Where, Y stands for GDP per capita which is a proxy to measure the economic growth; X_2 represents the share of REC in total energy consumption, β_2 is its coefficient of renewable energy consumption; i stands for the ith cross-sectional unit (i.e., country), β_{1i} stands for individual effect (country effect) and is an unknown parameter to be estimated. The existing empirical findings show that the size and nature of the impact of the increased share of consumption of renewable energy on economic growth differ between countries. This is due to the differential abilities of the countries to convert the resources into more growth. Cost, technologies, skills, public awareness, government policies, and support schemes such as subsidies, sectors/fields where such energy is utilized, etc. are the key factors in determining the ability of the countries to convert renewable energy sources into real economic growth.

Model-1 generated by simple linear regression estimation ignores such country-specific factors in governing the growth of the economy.

The following hypothesis is tested

Null and Alternative Hypothesis

PRIMARY HYPOTHESIS

H0: There is no relation between renewable energy consumption and economic growth in India

H1: There is a relation between renewable energy consumption and economic growth in India

Independent Variable: GDP of India

Dependent Variable: Renewable Energy Consumption of India

SECONDARY HYPOTHESIS

H0: There is no relation between renewable energy consumption and economic growth in India

H1: There is a relation between renewable energy consumption and economic growth in India

Independent Variable: GDP of USA

Dependent Variable: Renewable Energy Consumption of USA

5.0 Data

Table A1: Share of renewable energy consumption out of total energy consumption in India and GDP at constant US$; REC: Share of Renewable Energy Consumption in total energy consumption

YEAR	REC	GDP
1990	58.65286	3.21E+11
1991	57.60479	2.7E+11
1992	57.23057	2.88E+11
1993	56.98336	2.79E+11
1994	55.55719	3.27E+11
1995	54.48412	3.6E+11
1996	53.76741	3.93E+11
1997	52.48807	4.16E+11
1998	52.71226	4.21E+11
1999	51.71729	4.59E+11
2000	51.5537	4.68E+11
2001	51.8585	4.85E+11
2002	50.8081	5.15E+11
2003	50.8298	6.08E+11
2004	50.0728	7.09E+11
2005	48.5324	8.2E+11
2006	46.0632	9.4E+11
2007	44.9034	1.22E+12
2008	43.4051	1.2E+12
2009	42.1075	1.34E+12
2010	41.1128	1.68E+12
2011	40.5772	1.82E+12
2012	39.3461	1.83E+12
2013	38.1829	1.86E+12
2014	36.0538	2.04E+12
2015	34.3959	2.1E+12

2016	33.5629	2.29E+12
2017	32.2121	2.65E+12
2018	31.6892	2.7E+12

Source: World Development Indicators

There is a fall in renewable energy consumption over the years from1990 to 2018. However, it shows a slight upturn in 1998, 2001,2003. During the same period, it shows a consistent increase in the GDP of the country except for 1991 and 1993. This may have happened because of the increasing cost incurred due to the consumption of renewable energy.

Table A2: Share of renewable energy consumption out of total energy consumption in the USA and GDP at constant US$; REC: Share of Renewable Energy Consumption in total energy consumption

YEAR	**GDP**	**REC**
1990	5.96E+12	4.175462
1991	6.16E+12	4.50792
1992	6.52E+12	4.763083
1993	6.86E+12	4.281528
1994	7.29E+12	4.088641
1995	7.64E+12	4.726554
1996	8.07E+12	4.76393
1997	8.58E+12	4.51426
1998	9.06E+12	4.534297
1999	9.63E+12	5.709727
2000	1.03E+13	5.4297
2001	1.06E+13	4.6787
2002	1.09E+13	4.8408
2003	1.15E+13	5.3263
2004	1.22E+13	5.4777
2005	1.3E+13	5.8412
2006	1.38E+13	6.3967

2007	1.45E+13	6.3042
2008	1.47E+13	6.8456
2009	1.44E+13	7.3544
2010	1.5E+13	7.4357
2011	1.55E+13	8.3642
2012	1.62E+13	8.7281
2013	1.68E+13	9.0833
2014	1.75E+13	9.2205
2015	1.82E+13	9.0339
2016	1.87E+13	9.4563
2017	1.95E+13	9.9191
2018	2.06E+13	10.1072

Source: World Development Indicators

There is a rise in renewable energy consumption over the years from1990 to 2018. However, it shows a slight downturn in 2009 due to the Great Recession. During the same period, it shows a consistent increase in the GDP of the country except for 1993,1994,1997, and 2001. This may have happened because of the reduced cost incurred due to renewable energy consumption due to proper infrastructure facilities and skills.

6.0 Identification of Trend Rate and Consumption

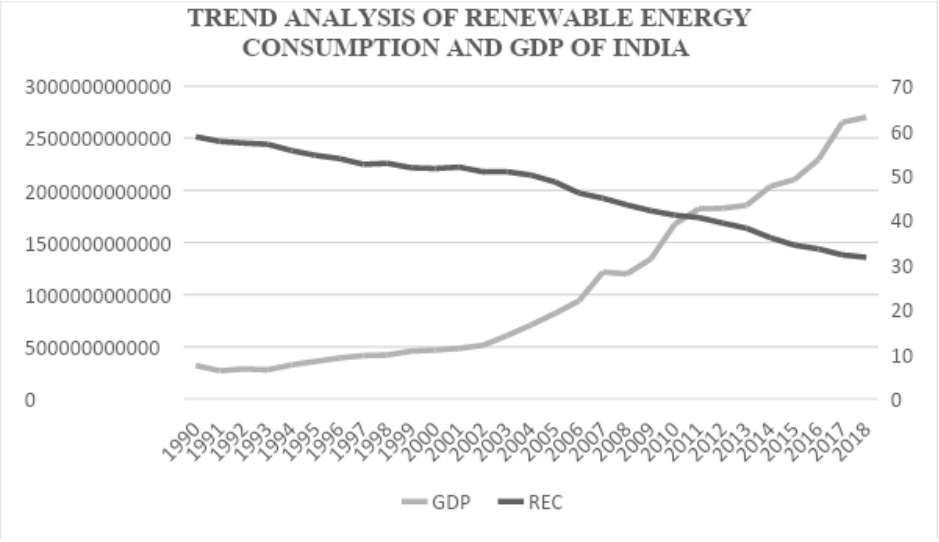


Chart 1.1: Trend of Renewable energy consumption (Black) and GDP in India (Grey)

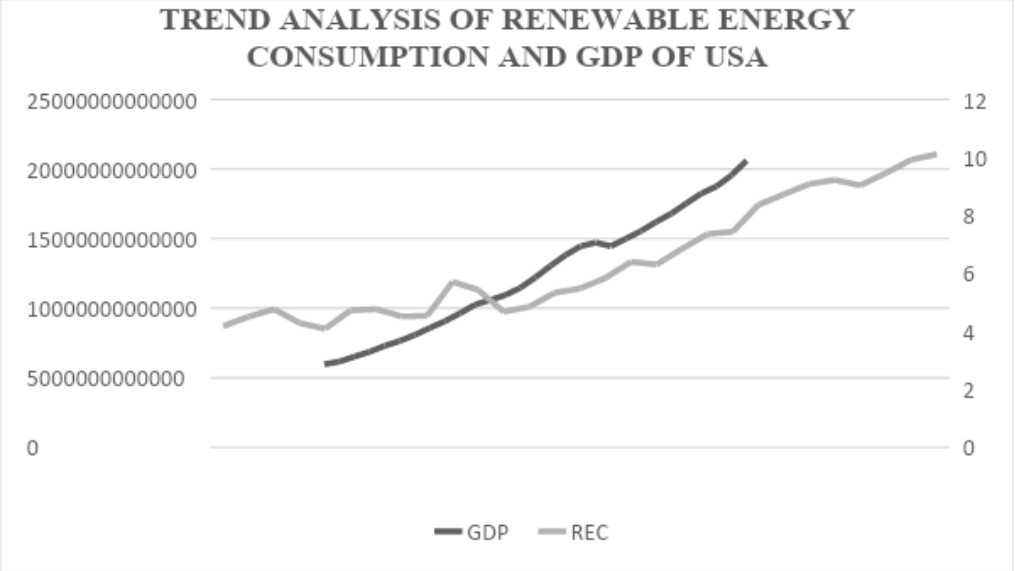


Chart 1.2: Trend of Renewable energy consumption (Black) and GDP in the USA (Grey)
Source: Author's calculations

From chart 1.1 we can conclude that there is an inverse relationship between renewable energy consumption and GDP in India. Over the period 1990 to 2018, as GDP increases the share of renewable energy decreases. Therefore, there is a decreasing trend in renewable energy consumption as compared to the increasing trend in GDP. However, in chart 1.2, we can say that there is an increasing trend in renewable energy consumption and GDP in the USA. This has been presented in tables A1 and A2.

7.0 Regression Results and Analysis

The model has been estimated separately for both the countries using a simple linear regression method with the share of renewable energy consumption as a dependent variable and GDP as the independent variable and the results are as follows:

Table1: Regression result: Economic growth from Renewable Energy Consumption in India

Regression Statistics	
Multiple R	0.98181
R Square	0.963951
Adjusted R Square	0.962616
Standard Error	1.53E+11
Observations	29

	df	SS	MS	F	Significance F
Regression	1	1.69E+25	1.69E+25	721.9835	5.1E-21
Residual	27	6.31E+23	2.34E+22		
Total	28	1.75E+25			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	5.41E+12	1.64E+11	32.93844	2.45E-23	5.07E+12	5.74E+12	5.07E+12	5.74E+12
REC	-9.3E+10	3.45E+09	-26.8697	5.1E-21	-1E+11	-8.6E+10	-1E+11	-8.6E+10

Source: Author's calculation

The regression results show that India's economic growth is largely affected by the consumption of renewable energy. It has been found that REC has a negative effect on India's economic growth. An increase in the share of renewable energy consumption will have an adverse impact on the economic growth of India.

Table2: Regression result: Economic growth from Renewable Energy Consumption in USA

Regression Statistics	
Multiple R	0.954425
R Square	0.910928
Adjusted R Square	0.907629
Standard Error	1.34E+12
Observations	29

	df	SS	MS	F	Significance F
Regression	1	4.95E+26	4.95E+26	276.1242	1.05E-15
Residual	27	4.84E+25	1.79E+24		
Total	28	5.43E+26			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-1.1E+12	8.49E+11	-1.27411	0.213484	-2.8E+12	6.6E+11	-2.8E+12	6.6E+11
REC	2.1E+12	1.27E+11	16.61699	1.05E-15	1.84E+12	2.36E+12	1.84E+12	2.36E+12

Source: Author's calculation

The regression results show that the economic growth of the USA is largely affected by the consumption of renewable energy. It has been found that REC has a positive effect on India's economic growth. An increase in the share of renewable energy consumption will have a positive impact on the economic growth of the USA.

8.0 Interpretation

For India, when the consumption of renewable energy increases by 1 unit it leads to a decline of GDP by 9.3E+10 units. However, the p-value states that the result is significant at a 1% level and there is enough evidence to reject the null hypothesis. The R square value is very high; therefore, it is a good regression model, so renewable energy consumption is one of the major factors determining the economic growth of India. This is shown in table 1.

In the case of the USA, when the consumption of renewable energy increases by 1 unit it leads to an increase in GDP by 2.1E+12 units. However, the p-value states that the result is significant at a 1% level and there is enough evidence to reject the null hypothesis. The R square value is very high; therefore, it is a good regression model, so renewable energy consumption is one of the major factors determining the economic growth of the USA. This is shown in table 2.

The economic growth of India and the USA is governed significantly by renewable energy factors, one of which is renewable energy consumption. In the case of India, renewable energy consumption has an adverse relation to the economic growth of the country whereas, in the case of the USA, there is a positive relationship between the two. This disagrees with the results of several studies which show a positive impact of renewable energy consumption on economic growth. It can be said that there are investments involving huge amounts of economic costs in terms of GDP per capita. Thus, the results in the case of India support the growth hypothesis.

There are major differences between USA and India's monetary and fiscal policies, social democracy, demographic composition, production, technology, and resources. These discrepancies across nations may result in disparities in their contributions to their country's growth. Thus, there can be factors apart from renewable energy consumption which is responsible for the country's economic growth. A similar trend was observed in the case of BRICS countries as well [4].

9.0 Limitations of the Study

There are other factors affecting the economic growth of a country other than renewable energy consumption that has not been included in the regression analysis. The inclusion of other control variables may affect the result. This leaves scope for future research. However, this is considered a limitation of the present study.

As the dataset used in the study is time-series data, the application of the Granger Causality method instead of the OLS Regression may have produced better results than the present one.

The country-specific factors for economic growth have not been considered. The inclusion of those factors may alter the result.

10.0 Conclusion

Across the world, there have been discussions about the usage of renewable sources of energy and how it would lead to sustainable growth in place of the non-renewable sources of energy which led to pollution, global warming, and climate change. Contrary to popular belief, the findings of this study do not support the generally held assumption that investing in the production and use of renewable energy will increase growth. It has been shown that governments suffer higher economic costs and slower economic growth while switching from traditional energy to renewable energy in the case of developing countries like India but the results are the opposite in the case of developed countries like the USA. The findings of this paper are consistent with the growth hypothesis in the case of India but not in the case of the USA. A huge part of the budget of each country is allocated towards the improvement of the renewable energy sector by harnessing wind energy, solar energy, water resources, etc. However, the transition is very rough and involves huge production and consumption costs which lead to a negative impact on the growth of developing countries whereas, in the case of developed countries, it has a positive impact and proves to reduce extra costs. This is because of renewable energy policies, proper infrastructure, funding, skilled labour, capital, and public awareness which has been involved to develop the renewable energy sector.

Despite the negative consequences, the focus must remain on clean and sustainable energy. Policymakers of developing countries must examine their domestic renewable energy policies and identify the primary country-specific variables that are negatively impacting growth. The negative impact will be mitigated through the formulation of realistic and result-oriented policies, as well as their successful execution.

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