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The Dynamics of R&D Expenditure, Renewable Electricity Production, and Economic Growth: A Comparative Analysis of Norway and Brazil

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Abstract: In the quest to secure energy supply and mitigate dependence on imported fossil fuels, nations are diversifying into renewable energy sources (RES). This study investigates the impact of renewable electricity production on economic growth, alongside the interplay with research and development (R&D) expenditures, through a comparative lens focusing on Norway and Brazil—both pioneers in the renewable energy arena. Analysis incorporates per capita R&D expenditures to gauge the nexus between renewable energy initiatives and R&D investment, employing data spanning from 2003 to 2014. The investigation reveals a notable divergence between the two nations. In Norway, no significant link was identified between the volume of renewable energy produced and per capita R&D expenditures. Nonetheless, a causal connection between economic growth and R&D investment was observed, with a robust correlation suggesting a profound influence of economic expansion on R&D activities. Contrarily, Brazil's scenario delineates a unidirectional causal relationship where economic growth positively influences the renewable energy sector, with no discernible association between R&D expenditures per capita and economic growth. These findings underscore the variegated impacts of renewable energy policies and R&D investments on economic dynamics within the context of Norway and Brazil, highlighting the necessity for tailored approaches in leveraging renewable energy for sustainable development.

Keywords: Economic growth; Electricity production; Research and development (R&D) expenditures; Renewable energy; Renewable electricity; Norway; Brazil

1 Introduction

RES are being used more and more in European power production due to aggressive climate legislation [1]. Periods of good conditions and high electricity prices for wind power and small hydropower are causing many investors to plan new energy projects in Norway [2]. In contrast, in Europe, the growing proportion of RES in the production of electricity has led to a greater significance of the indirect economic impacts and the transfer of effects to other sectors and participants [3].

To effectively address climate change, it is necessary to swiftly substitute fossil-carbon energy sources. This should happen concurrently with a continuous rise in overall world energy demand [4]. A fully renewable electricity system in most countries relies heavily on wind and solar power. Studies focusing on wind energy have been conducted in the literature on renewable scarcity periods [5–8]. Nevertheless, the feasibility of achieving a fully sustainable power supply composed entirely of renewable sources is a subject of ongoing debate [4, 9–12].

Extensive research has been carried out on the subject of achieving electricity or energy that is entirely derived from renewable sources [9, 13–17]. The use of renewable power, together with the sustainable management of natural resources and advancements in energy technology, contributes to the improvement of environmental conditions. Additionally, the relationship between trade liberalization and economic development, when combined with the consumption of renewable electricity, has a favorable effect on the reduction of CO_2 emissions [18].

According to 2018 data, Denmark is famous for wind power generation (20%), Finland is famous for a lot of biomass energy for cogeneration and heating (79%), and Norway ranks first with hydroelectric power (81%).

Compared to Finland (41%) and Denmark (36%), the share of renewable energy is particularly high in Norway (73%) and Sweden (55%) [19]. Ranta, Laihanen, and Karhunen [19] conducted research that compared the bioenergy and renewable energy status in the Scandinavian nations of Finland, Sweden, Denmark, and Norway. Norway has the highest hydropower generation in Europe, with hydropower accounting for around 98.5% of electricity production. Norway also has excellent wind energy potential [20].

Brazil has conducted special tenders to increase its capacity since 2009 and has been at the forefront of implementing competitive bidding processes. The National Climate Change Policy was authorized by the government in 2009. The drought experienced in 2014-2015 intensified the need to expand the variety of energy sources and encourage the use of renewable energy. However, Brazil acts in partnership with China in its renewable energy policy [21].

The COVID-19 epidemic has had substantial effects on energy consumption in several nations [22]. It should be noted that there are studies proving the increase in electrical energy consumption during the COVID-19 period. Rouleau and Gosselin [23] performed research in a Canadian social housing complex during a 4-month lockdown. The study revealed that, on average, there was a marginal 2% rise in daily power use, but daily hot water usage saw a tiny 3% drop. A research investigation was carried out by Birch et al. [24] at a laboratory facility located on a university campus that consumes a significant amount of energy. Following the quarantine, it was ascertained that the sporadic use of power in the laboratory resulted in a 50% reduction in energy consumption.

In their research, Ding et al. [22] aimed to uncover possible issues related to power consumption patterns in four different kinds of buildings that rely on electric heating systems, particularly when faced with unforeseen disruptions. They discovered that the expansion of renewable energy production led to a rise in energy demand instead of a decrease in the use of fossil fuels. This, in turn, necessitated a greater requirement for producing capacity, beyond a simple one-to-one replacement with fossil fuels [25].

To mitigate the risk of harmful human-induced disruption to the climate system, it is said that RES have the potential to fulfill 50% of the global energy demand by 2050 [26]. In the last decade, the wind energy industry has been growing at an increasing rate [6]. Fei et al. [27] investigated the cause-and-effect connection between technical innovation, CO_2 emissions, economic development, and renewable energy in New Zealand and Norway from 1971 to 2010. As a result of the study, it was found that technological innovation plays an important role in the clean energy-growth link. The degree of political risk and its effect on the economic viability of renewable energy projects using a state assistance program in the Russian energy market were examined by Chebotareva [28].

There is a contention that a clear correlation exists between economic development and environmental quality, which undergoes a shift after a certain income level is attained [29, 30]. Power systems have seen technological advancements and a redefinition of key players in relation to energy supply and demand. In light of the growing prevalence of distributed renewable production and the active participation of small to medium customers on the supply side, it is imperative to effectively integrate decentralized units into the power system. An effective strategy to facilitate this transition is proposed by local power markets [31].

Enhancements in energy efficiency can diminish the necessity for investing in energy infrastructure, lower fuel expenses, enhance competitiveness, bolster energy security by diminishing reliance on imported fossil fuels, and additionally aid in safeguarding the environment by curbing greenhouse gas emissions and local air pollution [32]. Investing in R&D in the energy industry fosters energy technologies that decrease energy intensity and enhance environmental quality via the reduction of carbon emissions [18, 33]. Technological developments and R&D expenditures in the field of energy increase energy efficiency or reduce the costs of using environmentally friendly renewable energy [34].

As demonstrated by Chen et al. [35], long-term electricity market surveys indicate that there is great uncertainty about future electricity prices. For this, it is necessary to conduct comparative studies in different countries. Within the scope of the study, the causal relationship between three main variables was examined. In this context, Norway and Brazil, which are leaders in the world in terms of renewable energy production, were selected. All three variables were tested with the Granger analysis method in these two countries. This perspective led to the examination of the effects of renewable energy use on economic growth and the relationship between renewable energy resources and R&D expenditures in this study, which was based on data from 2003 to 2014 and looked at the renewable energy policies of Norway and Brazil, the two leading nations in the renewable energy sector.

2 Literature Review

In order to achieve a sustainable environment, the role of renewable energy R&D, as well as environmental R&D expenditure, is important [36]. Renewable energy technologies play an important role in solving global energy and environmental problems, and the speed of the energy transition directly depends on increasing their efficiency. Today, the development and implementation of renewable energy systems are provided mainly with state financing, which has limited possibilities [37]. Considering that the natural resources that are depleted around the world are left to future generations, the importance of renewable energy resources on a global scale is increasing day by day.

For this reason, various studies on RES have been carried out in different countries. Here, reviews of studies on renewable energy resources in different countries are included.

2.1 Renewable Electricity Production

Roughly half of all emissions come from land transportation, heating, and electricity generation. Numerous studies agree that using technologies already in mass production, electrical conversion to renewable energy, together with electrification of ground transportation and urban heating, may result in significant reductions in global emissions [14].

Norway is dedicated to pursuing aggressive climate targets in the future, such as cutting greenhouse gas emissions by 80-95% by 2050 (using 1990 as a baseline) and by at least 40% by 2030. Norway intends to decarbonize the transportation, industrial, and construction sectors—where electrification is anticipated to play a significant role—because these reductions cannot come from the energy sector. This entails, among other things, a 50% decrease in transportation-related CO_2 emissions before 2030 (using 2005 as a baseline). Based on "new" renewable sources, it is anticipated that these changes would result in an increase in local power output of between 30 and 50 TWh [38].

Hydropower is the largest renewable source of electricity in Europe. For this reason, countries with significant hydroelectric assets dominate total renewable energy production. However, Norway, one of the major hydropower producers, does not belong to the European Union. With more hydropower than any other member state of the European Union, Norway's capacity in 2008 was 29,700 MW [20]. According to Chen et al. [35], the predicted wind power capacity in the Scandinavian nations by 2040 will vary from 25 GW to 82 GW. In a similar vein, Norway's 2040 generation capacity varies from 39 to 68 GW. Forecasts for Scandinavian consumption in 2040 vary from 409 to 680 TWh, with electric cars accounting for 7-9% of that total [25].

Brazil's power generation includes a large hydroelectric power asset [21]. About 7% of Brazil's electricity is produced from sugarcane biomass [39]. However, solar energy sources are one of the sources used in electricity production in Brazil.

One of the few nations in Latin America with research, development, and distribution (R&D) ties to China in the field of renewable energy is Brazil. While Brazil and China have collaborated in science since the 1980s, the Joint Action Plan (2010-2014) was created to foster R&D collaboration in the renewable energy industry [21].

Due to the rise in distributed energy sources, power networks have undergone significant structural modifications that have resulted in local electricity markets. The distribution of units in the energy system is the outcome of large investment cost reductions in small-scale flexibility assets and generation [31]. Additionally, tenders are now the most extensively used method for acquiring renewable energy projects globally. Brazil has a significant position in this context. Specifically, nations that are new to auctions often find it difficult to pique the attention of enough bidders, which limits competition and drives up project costs. Being a leader in the use of auctions to promote investment in renewable energy projects, Brazil not only offers valuable insights into how to structure and conduct auctions to foster competition and produce successful investment outcomes but also shows how auctions are integral to the nation's growth [40].

With the passage of legislation governing the use of RES in 1997, Brazil made strides toward renewable energy. Ten-Year Energy Expansion Plans (PDEs), which contain precise objectives for renewable energy, constitute the nation's medium-term energy strategy. For instance, PDE 2023 sets the goal of 86.1% of the energy matrix being represented by RES [21]. In the study conducted by Huseynli and Huseynli [41], the relationship between conventional energy production, renewable energy production, and unemployment rates was examined.

A study by Curto et al. [13] examines electricity production and consumption on the small Italian island of Lampedusa. Many tiny, off-grid islands in the world still rely on fossil fuels. This is no longer viable from an economic or environmental standpoint, considering the high cost of producing power and the large emissions of pollutants. In order to meet certain decarbonization targets, the authors of the paper investigate the switch to an economically and technically feasible generating system based on solar, wind, and sea wave facilities.

Ohlendorf and Schill [8] examined free software and 40 years of reanalysis data for onshore wind generation in Germany. The study's findings showed that although low wind power episodes were more equally distributed throughout the year, they were less common in the winter than in the summer. In Norway, a country where renewable energy is the predominant source of energy, Jastad et al. [25] looked at several risk variables for future power costs and market values for renewable energy. In the study by Almoallem [42], the kind, size, and age of the homes in Jeddah, Saudi Arabia, were taken into consideration while analyzing the electricity consumption of the locals.

2.2 R&D Expenditures

R&D has a very important place in the energy sector. Energy extraction, transportation, energy integration, energy storage, etc. In these fields, R&D studies play a significant role. Numerous studies [43–45] highlight the role that R&D play in economic growth. According to Grossman and Helpman [46], the primary driver of economic development is industrial innovation brought about by R&D spending. According to Aghion and Howitt [44], technical advancement is the foundation of growth and is the outcome of rivalry between research organizations that prioritize innovation. Technological advancement was represented by Barro and Sala-i Martin [45] as the improvement of intermediary commodities for the manufacturing process. R&D, which is considered an additional input in the DEA model proposed by Conrad [47], has been found to improve energy efficiency by increasing R&D expenditures when technological change is embodied. In a study by Wei et al. [48], the energy efficiency changes of China's iron and steel industries were examined. Using an empirical dataset encompassing battery storage technology, Kittner et al. [49] investigated distribution and innovation using a two-factor model that integrated the value of investment in material innovation and technology deployment across time.

Economic growth is strongly correlated with energy R&D spending, energy consumption, financial development, foreign direct investment, and the public budget. According to Shahbaz et al. [50], there is a negative correlation between public spending on energy R&D and carbon emissions. This suggests that funding for energy innovations through R&D can improve environmental quality by lowering carbon emissions.

The study's findings showed that giving varying weights to various R&D metrics produces a varied ranking of businesses. This, in turn, enables R&D managers to use their understanding of the significance of various R&D metrics to develop more successful strategies and enhance the R&D performance of their organizations. completed. In the research by Ravšelj and Aristovnik [51], a panel data set of 1372 enterprises was used to examine the impact of R&D tax incentives and private R&D spending on sustainable company growth. Upon completion of the analysis, it was concluded that in a subset of Organization for Economic Cooperation and Development (OECD) countries, private R&D spending together with R&D tax incentives positively impact long-term business growth at the company level.

2.3 Economic Growth

The link between the usage of alternative and RES and economic development has been the subject of several studies [52–57]. Vaona [58] looked at how much energy comes from non-renewable sources. Economic expansion has a long-term beneficial impact on energy consumption and carbon emissions, according to Soytaş et al. [59]. Apergis et al. [52] looked at the causal connections between economic development, nuclear and renewable energy, and CO_2 emissions for a sample of 19 industrialized and developing nations between 1984 and 2007.

For a panel of chosen OECD nations, Ben Jebli et al. [60] examined the consequences of renewable energy usage via its dynamic link with international commerce, production, non-renewable energy use, and pollutant emissions. Mulder and Scholtens [61] used a reduced-form equation to study the impact of renewable energy on power costs in the Netherlands from 2006 to 2011. The study's conclusion was that Dutch power costs are adversely impacted by Germany's average wind speed. RES have become widespread in Germany and the Netherlands. In these countries, renewable energy is becoming a factor that can affect economic growth. Using a sectoral energy-economic econometric model (SEEEM), Blazejczak et al. [62] investigated the net economic effect related to the deployment of RES in Germany by 2030. The study's findings indicated a net beneficial impact on Germany's economic development. Balsalobre-Lorente et al. [18] looked at the relationship between consumption of renewable electricity and economic growth.

Based on a 10-year time series of data from 2003 to 2012, Jumiana's research [63] examined the relationship between export and development expenditures and Indonesia's economic growth, as well as the factors that have the greatest effect on that growth. The study's findings indicate that the development spending coefficient has little bearing on the state of the Indonesian economy. According to yearly data from 1980 to 2018, Kayesh and Siddiqa's research [64] looked at the outcomes of Bangladesh's energy transition as well as the causal links between economic development, renewable energy, and natural gas consumption. In the study conducted by Huseynli [65], the effect of investments in R&D on the acceleration of economic growth was examined in the cases of Azerbaijan, Kazakhstan, and Kyrgyzstan.

Ekinci et al. [66] used data between 2004 and 2019 to examine the impact of health R&D expenditures on economic growth at the level of 10 countries (Czech Republic, Hungary, Korea, Poland, Portugal, Slovakia, Turkey, Romania, Russia, and South Africa). In the study conducted by Tung and Hoang [67], the effect of R&D expenditures on economic growth was investigated with a sample of 29 developing economies in the period between 1996 and 2019.

3 Research Methodology

3.1 Purpose of the Study

The aim of this study is to analyze the effects of renewable energy use on economic growth and the relationship of renewable energy resources with R&D expenditures from the perspective of the renewable energy policies of Norway and Brazil, which are the leading countries in the renewable energy sector, based on the data between 2003 and 2014. Since the data obtained from the World Bank is limited to 2014, the data includes the years 2003–2014.

The efforts made for a greener world after 2013 have increased investments and demand in the renewable energy sector. As a matter of fact, today, countries organize a number of economic and social events to draw attention to the renewable energy sector and engage in activities to increase literacy knowledge in this field. In this context, having more time could have possibly resulted in a result related to R&D studies. Although it is possible to access platforms other than the World Bank that provide information on energy resources, unfortunately, it has not been possible to access information within the scope of renewable energy. For this reason, in order to increase the reliability of the analysis, it was decided to draw all data from the same source, and all data was obtained from the World Bank. The World Bank, on the other hand, did not disclose data on renewable energy until 2014.

3.2 Data Set and Analysis Method

In the study, in order to measure the effects of electrical energy obtained from renewable sources on economic growth and its relationship with R&D expenditures, renewable electrical energy production, per capita R&D expenditures, and economic growth data were compiled and analyzed with the Granger method in the period between 2003 and 2014. Information on the wage policy allocated to R&D expenditures per capita over the years in the countries examined as an example before the analysis is shown in Figure 1 and Figure 2. In these graphs, it is possible to see that R&D expenditures play an inevitable role in developing economies, and therefore the appropriations paid increase every year.

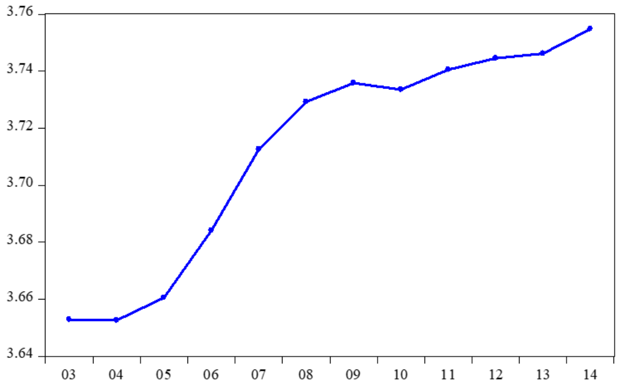

Figure 1. R&D expenditure per capita in Norway

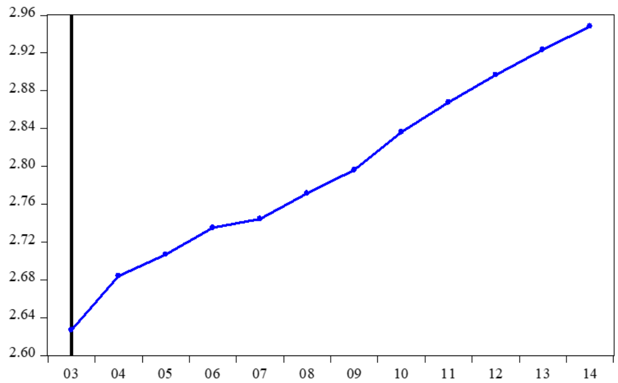

Figure 2. R&D expenditure per capita in Brazil

There are different analysis methods in the literature to measure the causal relationship between variables. However, when a literature review was conducted within the framework of similar studies, it was concluded that one of the most preferred methods was the Granger method in order to provide more reliable results within the scope of causality, and it was determined to be the appropriate method for the analysis part of the study. In addition, a series of assumption tests were applied before the Granger causality test for reliable analysis results. The variables included in the analysis are GDP, renewable energy production, and R&D expenditures. GDP is considered a dollar-denominated increase over the years at the country level. R&D expenditures are shown based on R&D expenditures per capita within countries. Renewable energy production shows the amount of renewable energy within the total amount of energy produced over the years in both countries.

4 Analysis and Results

Within the scope of Granger analysis, first of all, it was tested whether the data sets contained unit roots at each level. As a result of the stationarity test (Extended Dickey-Fuller (ADF)), it was observed that the data set was not stationary at level values. Explanations regarding the non-stationary data set are given in Table 1.

Table 1. Level values of series in Norway and Brazil

Norway							
		Renewable Electricity Production		**R&D Expenditure per Capita**		**GDP**	
ADF Testing Statistics		t-statistics	p-value	t-statistics	p-value	t-statistics	p-value
		-1.397621	0.5442	-1.229855	0.6203	-2.394228	0.1642
Test Critical Values	**%1**	-4.200056		-4.200056		-4.200056	
	%5	-3.175352		-3.175352		-3.175352	
	%10	-2.728985		-2.728985		-2.728985	
Brazil							
		Renewable Electricity Production		**R&D Expenditure per Capita**		**GDP**	
ADF Testing Statistics		t-statistics	p-value	t-statistics	p-value	t-statistics	p-value
		2.147791	0.9993	-0.932061	0.7366	-2.719849	0.0869
Test Critical Values	**%1**	-4.297073		-4.200056		-4.200056	
	%5	-3.212696		-3.175352		-3.175352	
	%10	-2.747676		-2.728985		-2.728985	

Following the execution of the appropriate procedures intended to ensure the consistency of the data, it was discovered that the variables at the second level were stable. The VAR model was used after it was determined that these data are stationary to the second order after having obtained that conclusion. Table 2 presents the findings in relation to the stationarity levels of the series.

Table 2. Second order stationarity values in Norway and Brazil

Norway							
		Renewable Electricity Production		**R&D Expenditure per Capita**		**GDP**	
ADF Testing Statistics		t-statistics	p-value	t-statistics	p-value	t-statistics	p-value
		-3.605339	0.0025	2.888162	0.0415	-3.619613	0.0029
Test Critical Values	**%1**	-2.847250		-2.847250		-2.886101	
	%5	-1.988198		-1.988198		-1.995865	
	%10	-1.600140		-1.600140		-1.599088	
Brazil							
		Renewable Electricity Production		**R&D Expenditure per Capita**		**GDP**	
ADF Testing Statistics		t-statistics	p-value	t-statistics	p-value	t-statistics	p-value
		-9.004988	0.0000	-3.654024	0.0032	-3.632714	0.0028
Test Critical Values	**%1**	-2.847250		-2.937216		-2.886101	
	%5	-1.988198		-2.006292		-1.995865	
	%10	-1.600140		-1.598068		-1.599088	

Table 3. Appropriate delay length in Norway

Lag	LogL	LR	FPE	AIC	SC	HQ
0	83.55468	NA	2.03e-11	-16.11094	-16.02016	-16.21052
1	111.0789	33.02900*	5.73e-13	-19.81577	-19.45267	-20.21409
2	128.1971	10.27093	2.68e-13*	-21.43941*	-20.80398*	-22.13648*

*Indicates the appropriate lag length for the relevant test

The ideal lag duration has to be established before the VAR model can be used. The lag duration is ascertained using the Likelihood Ratio Test (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), and Hannan-Quinn (HQ) tests. Table 3 displays the suitable lag duration for Norway.

Table 4 shows the appropriate lag length for Brazil. It is understood from the tables that the appropriate lag length created for this data set was determined to be 2 for both countries.

Following the completion of all the required tests and the establishment of a suitable lag duration, the Granger analysis was initiated. Table 5 presents the findings on Granger causality for the various data sets.

Table 4. Appropriate delay length in Brazil

Lag	LogL	LR	FPE	AIC	SC	HQ
0	55.19818	NA	5.88e-09	-10.43964	-10.34886	-10.53922
1	89.02843	40.59630*	4.72e-11*	-15.40569*	-15.04258*	-15.80401*
2	95.92126	4.135699	1.70e-10	-14.98425	-14.34882	-15.68132

*Indicates the appropriate lag length for the relevant test

Table 5. Results of the Granger causality test in Norway and Brazil

Hypotheses	F-Value	Probability Value (p)	Decision at 5% Significance Level
R&D expenditures per capita in Norway are the cause of renewable electricity generation	1.764922	0.4138	Rejected
Norway's economic growth is the reason for the country's renewable electricity generation	0.363873	0.8337	Rejected
Renewable electricity generation in Norway is the reason for the country's increased per capita R&D expenditure	5.110442	0.0777	Rejected
Norway's economic growth is the reason for the country's increased per capita R&D spending	7.513669	0.0234	Accepted
Increasing renewable electricity generation in Norway is the reason for the country's economic growth	4.725217	0.0942	Rejected
The increase in R&D expenditures per capita in Norway is the reason for the country's economic growth	2.612911	0.2708	Rejected
Rl&D expenditures in Brazil are the cause of renewable electricity generation	5.606408	0.0606	Rejected
Brazil's economic growth is the reason for the country's renewable electricity generation	6.049835	0.0486	Accepted
Renewable electricity generation in Brazil is the reason for the country's increase in R&D expenditures per capita	0.628478	0.7303	Rejected
Brazil's economic growth is the reason for the country's increased per capita Rl&D spending	0.214937	0.8981	Rejected
The increase in renewable electricity production in Brazil is the reason for the country's economic growth	0.704843	0.7030	Rejected
The increase in R &D expenditures per capita in Brazil is the reason for the country's economic growth	0.148795	0.9283	Rejected

In terms of both countries, the relationship between renewable electricity production, per capita R&D expenditures, and economic growth variables was subjected to Granger causality analysis, and information on the results of the test is given in Table 5. The hypotheses created during the study were divided into two groups:

• H0: There is no causal relationship between the variables.

• H1: There is a causal relationship between the variables.

Similarly, the results of the correlation test applied to the data are also included in Table 6.

Table 6. Results of correlation analysis in Norway and Brazil

	Norway		
	Renewable Electricity Production	**R&D Expenditures per Capita**	**Economic Growth**
Renewable Electricity Production	1	-0.693	-0.554
R&D Expenditures per Capita	-0.693	1	0.949
Economic Growth	-0.554	0.949	1
	Brazil		
	Economic Growth	**R&D Expenditures per Capita**	**Renewable Electricity Production**
Economic Growth	1	0.943	-0.509
R&D Expenditures per Capita	0.943	1	-0.727
Renewable Electricity Production	-0.509	-0.727	1

According to the results of the Granger causality test, no relationship was found between the amount of energy produced from renewable resources and R&D expenditures per capita for both countries. However, a causal relationship was found between economic growth and R&D expenditures in Norway. In other words, economic growth in this country is the Granger cause of R&D expenditures. As a result of the correlation relationship, it is seen that the relationship between economic growth and R&D data in Norway is very strong. This information is also valid for Brazil. A unilateral causality relationship between economic growth and renewable energy was obtained for Brazil. In other words, it is possible to positively affect the renewable energy sector by increasing the GDP in this country. In addition, it is seen that there is a strong correlation between R&D expenditures per capita and economic growth in Brazil.

5 Discussion and Conclusion

Energy policies of today are founded on three fundamental tenets: preserving the environment, addressing climate change, and guaranteeing the security of the energy supply. These tenets include creating a competitive, transparent, and fully integrated domestic market in the electricity and natural gas sectors. The goal of a long-term energy strategy is to provide energy that is sustainable, inexpensive for all customers, whether they are business or residential, and considerate of the environment.

The increasing body of research showing that the use of RES boosts economic development indicates that these sources must be supported in the fight against global warming. As a result, it is evident that most nations promote the use of RES, and energy regulations also support investments in alternative energy sources. It is observed that R&D expenditures are also supported by the states in this direction.

Similar studies have been done on this subject in the literature before. We can briefly summarize the studies on similar studies and the results obtained. According to Vaona's [58] research, economic growth is facilitated by higher non-renewable energy consumption, but as production increases, non-renewable energy consumption grows less quickly. According to research by Ranta, Laihanen, and Karhunen [19], the EU is falling short of the 20% objective, although all Nordic nations have high rates of renewable energy consumption and have already surpassed the gross final energy consumption target set by the Europe 2020 plan. As a result of the study by Curto et al. [13], to meet 40% of Lampedusa's current electricity demand, optimal solutions, including 1509 kW from photovoltaic plants, 2100 kW from wind turbines, and 640 kW from wave energy converters, indicate the need for a mix of energy. In this way, the actual cost of electricity generation can be reduced from the current value of 0.282 €/kWh to 0.260 €/kWh. According to research by Almoallem [42] using the Saudi Arabian city of Jeddah as an example, using window glazing systems would cut electricity consumption by 11%, and using thermal insulation would cut electricity consumption by 14%. Considering the many unknowns in the energy industry, it is critical to comprehend how market values react to various circumstances and the potential ramifications for the switch to renewable energy [25].

According to the findings obtained from the analysis, no relationship was found between the amount of energy produced from renewable resources and R&D expenditures per capita. Nonetheless, in Norway, a causal link was shown between R&D spending and economic development. The correlation connection shows that there is a substantial association in Norway between R&D data and economic development. This information also applies to Brazil. A unilateral causality relationship between economic growth and renewable energy was also obtained for Brazil. In other words, it is possible to positively affect the renewable energy sector by increasing the GDP in this country. In addition, it is seen that there is a strong correlation between R&D expenditures per capita and economic growth in Brazil. These findings, on the one hand, help the energy obtained from renewable resources, which is an important factor in the context of the sustainable development process, to achieve a more liveable environmental environment.

As a result of the analysis of the causal relationship between R&D expenditures per capita and renewable electricity production, no significant results were obtained, neither in Norway nor in Brazil. This means that in both Norway and Brazil, energy from RES is obtained mostly from natural sources and is not linked to state R&D investments.

As a result of the analysis of the causal relationship between economic growth and renewable electricity production, although the hypothesis was rejected in Norway, it was accepted in Brazil. Since Brazil is a developing country, renewable energy production affects economic growth. However, due to the magnitude of other factors affecting economic growth in Norway, renewable energy production does not directly affect it.

As a result of the analysis made between economic growth and R&D expenditures per capita, no relationship was detected in Brazil, but a causality was detected between these variables in Norway. As a developed country, Norway's expenditure on R&D per capita generally reflects itself in economic growth. In developing Brazil, this relationship was not significant.

Considering all these, and considering that Brazil's renewable energy production affects economic growth, it is thought that increasing the amount of spending that Brazil will allocate to R&D may also increase economic growth slightly. Considering the amount of renewable energy production, it seems that it will not be possible for renewable energy production to emerge as a causal factor affecting economic growth in Norway, which is one of the leading countries in the world. This may be due to the fact that other factors affecting Norway's economic growth have a more important share. Policymakers can take these results into consideration and use them in planning new strategies in both the economic, R&D, and renewable energy sectors.

Overall, policymakers can benefit from the experiences of both Norway and Brazil, as the implementation of green economic growth is also important for the implementation of carbon-free development policy. These findings, on the one hand, help the energy supplied from renewable resources, which is an important factor in the context of the sustainable development process, to achieve a more liveable environmental environment.

Author Contributions

Conceptualization, B.H.; methodology, B.H. and N.H.; validation, N.H., formal analysis, N.H.; investigation, N.H.; resources, B.H.; data curation, N.H.; writing—original draft preparation, B.H.; writing—review and editing, B.H.; visualization, B.H.; supervision, B.H. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest regarding this work.

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