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Renewable Energy in the Eurozone: Exploring Macroeconomic Impacts via FMOLS

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Abstract: This article examines the relationship between macroeconomic variables and the share of renewable energy in Eurozone countries from 2006 to 2020. Using the Fully Modified Ordinary Least Squares (FMOLS) method, we analyze the impact of Gross Domestic Product (GDP) per capita, unemployment rate, Financial Development Index (FDI), inflation, government efficiency, and corruption control on the proportion of renewable energy. Focused on the Eurozone, our study fills a gap in existing research. We compile diverse findings from the literature review on this topic. Our analysis reveals that higher GDP per capita positively influences the proportion of renewable energy, while unemployment, lower financial development, higher inflation, inefficient governance, and corruption negatively impact renewable energy adoption. These findings underscore the importance of addressing economic development alongside sustainable energy initiatives. Policymakers should prioritize improving GDP per capita, and addressing barriers such as unemployment and corruption to facilitate the transition to a more sustainable energy landscape in the Eurozone.

Keywords: renewable energy; Eurozone countries; FMOLS analysis; energy portfolio; sustainable development; economic growth

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1. Introduction

The urgent global need to address climate change and transition towards cleaner, more resilient energy systems has made sustainable energy solutions a central topic of contemporary discourse. Against the backdrop of escalating environmental concerns, countries worldwide are increasingly prioritizing the integration of renewable energy sources. This paradigm shift signifies not only a response to environmental imperatives but also a transformative journey toward diversified, resilient, and eco-friendly energy portfolios. Understanding the intricate relationships between macroeconomic variables and the utilization of renewable energy emerges as a key area of exploration in this context. This intersection of economic dynamics and renewable energy adoption holds profound implications for the trajectory of global energy landscapes and offers valuable insights into fostering sustainable development.

The study outlined in [1] provides up-to-date data concerning the utilization of renewable energy across various consumption sectors within the European Union (EU). Renewable energy encompasses a wide array of sustainable production methods, including wind power; solar power (thermal, photovoltaic, and concentrated forms); hydro power; tidal power; geothermal energy; heat harnessed through heat pumps; biofuels; and the renewable aspect of waste. The adoption of these renewable sources offers multifaceted advantages, including the mitigation of greenhouse gas emissions, the diversification of energy supplies, and the reduction of dependency on fossil fuel markets, notably oil and gas. Furthermore, the expansion of renewable energy presents an opportunity to stimulate employment within the EU through the creation of jobs in burgeoning 'green' technologies.

Renewable energy is widely recognized as a cleaner alternative to fossil fuel-based energy generation. According to the International Energy Agency (IEA) [2], renewable

energy is anticipated to be the fastest-growing source of global energy. The increasing investment in this form of energy production is believed to correlate with economic growth and development, although scholarly discourse remains divided on whether heightened economic growth drives increased adoption of renewable energies or vice versa. Projections indicate that renewable energy is poised to augment its share in the overall energy supply, rising from 13% in 2012 to an expected 18% in 2035 [3,4]. However, not all types of renewable energy show equal promise for the future; while wind and solar are growing rapidly at a rate of 7.8% annually, they still constitute less than 1% of global energy consumption [3,4].

Despite the potential of renewable energy technologies, they have not yet achieved cost-effectiveness, primarily due to a lack of intense competition. Given the elevated costs, it is anticipated that only affluent, developed nations will significantly contribute renewable energy to their power grids, despite the fact that developing countries possess abundant natural resources but lack the means or capital to exploit them [5].

This study is crucial for a better understanding of how macroeconomic factors contribute to the adoption of renewable energy, which has significant implications for economic development and the sustainable energy sector. Examining these variables can provide valuable insights into how policies and strategies in economic growth influence the transition to more sustainable energy systems. Focusing on macroeconomic variables is essential because these factors have a considerable impact on the structure and dynamics of economies, thus affecting their ability to adapt and support the transition to renewable energy sources. It is important to better understand how these variables influence decisions regarding investments in renewable energy sources and how they can be utilized to support sustainable development. Therefore, this research represents a key step in presenting appropriate policies and strategies to achieve a sustainable energy sector in the future.

In recent years, there has been a swift upsurge in the trend towards environmental sustainability through the widespread utilization of renewable energy sources. This dynamic raises the question of how macroeconomic variables influence the share of renewable energy. Therefore, our study aims to examine the relationship between the share of renewable energy and several key macroeconomic indicators, specifically Gross Domestic Product (GDP) per capita, population unemployment rate (UNM), the Financial Development Index (FDI), inflation (INF), government efficiency (GEF), and corruption control (CcC). Our research concentrates on Eurozone countries, as we find that this particular group of nations has not been examined in a similar study before. The timeframe for the data extends from 2006 to 2020, aiming to incorporate the most recent available information. However, data for the years 2021 and 2022 were not accessible at the time of this study.

The central research question explored in this investigation is: "Do macroeconomic factors collectively exert a substantial influence on the share of energy sourced from renewables in the Eurozone?" The structure of the article is outlined as follows. The introductory segment outlines the intersection of sustainable energy and macroeconomic factors (Section 1). Following that, we present a condensed overview of the theoretical framework concerning the analysis of how macroeconomic variables influence the proportion of renewable energy in Eurozone countries (Section 2). The methodology and data employed in the empirical phase of the article are outlined in Section 3. In Section 4, we execute the research, provide a summary of descriptive statistics for the variables utilized, and present the key findings. The outcomes presented in Section 5 are presented as a discussion, where they are juxtaposed with those of pivotal empirical studies in the research field, and we propose potential avenues for future exploration in this domain. Finally, Section 6 provides the conclusions of the study.

2. Literature Review

In an effort to understand the intricate relationships between energy sustainability and macroeconomic factors, this literature review compiles and analyzes existing studies that investigate the relationship between the Share of Energy from Renewable Sources and key

macroeconomic variables, including GDP, unemployment rate, the Financial Development Index, inflation, government effectiveness, and Control of Corruption.

2.1. Relationship between Share of Renewable Energy and GDP per Capita

The relationship between renewable energy in the electricity sector and GDP per capita was investigated in a study [6] conducted in European Union countries. Panel data models based on the data from 2007 to 2017 indicated a positive albeit minimal influence of GDP per capita on the proportion of renewable energy sources in electricity across EU countries. This trend was consistent except for Luxembourg, which exhibited exceptional values of GDP per capita. However, a causal relationship between these two variables was not identified. Clusters of countries were delineated according to these variables using cluster analysis. Subsequent studies should aim to enhance this model by integrating additional significant variables, such as the renewable energy potential inherent in countries with distinct geographical conditions.

The findings of study [7] indicate that renewable energy plays a significant role in reducing carbon emissions, with GDP per capita exhibiting an inverted U-shaped relationship with CO_2 emissions. This confirms the existence of the Environmental Kuznets Curve (EKC) for highly globalized countries. Several policy recommendations emerge from our study. Primarily, it is imperative for developing nations to elevate the proportion of energy derived from renewable sources. This shift would not only positively impact air quality but also foster economic growth. Therefore, it is vital to channel investments into renewable energy initiatives and create conducive environments and incentives to expedite the adoption of renewable technologies by both the private sector and households. Secondly, enhancing the investment climate's quality is paramount. Developing countries stand to gain significantly from investments driven by globalization, which can facilitate technology transfer, particularly within the energy sector. Thirdly, findings indicate that bolstering the status of women can markedly mitigate vulnerability to climate change. This objective can be realized through augmenting women's human capital and investing in organizations and communities led by women. The results from this literature suggest that the relationship between the share of renewable energy in the electricity sector and GDP per capita is positive, albeit minimal, with the exception of Luxembourg, which exhibited exceptionally high values of GDP per capita. However, a direct causal link between these two variables was not identified. Conclusions from further studies indicate that renewable energy plays a significant role in reducing CO_2 emissions, while GDP per capita exhibits an inverted U-shaped relationship with CO_2 emissions, thus confirming the existence of the Environmental Kuznets Curve (EKC) for highly globalized countries.

These findings have important implications for our study. Our work aims to determine how these relationships differ in the context of Eurozone countries from 2006 to 2020. The main objectives of our study are to assess how these macroeconomic factors influence the adoption of renewable energy in the Eurozone and to gain a more comprehensive understanding of the factors influencing this process.

These findings will enable us to formulate recommendations for policy and practice aimed at improving support for renewable energy sources within the Eurozone, which could have a positive impact on environmental and economic indicators in the region.

2.2. Relationship between Share of Renewable Energy and Unemployment

The relationship between the Share of Energy from Renewable Sources and unemployment has been examined by several authors, such as [8–10]. Using a three-sector general equilibrium model, the authors of [8] analyzed the impact of policies supporting renewable electricity on the equilibrium unemployment rate. In a simplified version of the model with two factors, they provided analytical evidence showing that policies aimed at supporting renewable electricity result in a rise in the unemployment rate. Particularly, under conditions where the elasticity of substitution between capital and labor is low, where capital lacks international mobility, and where there is high labor intensity in renewable energy

production relative to conventional production, policies promoting renewable electricity could lower the equilibrium unemployment rate. The analysis is conducted using the example of the US economy. The relationship between renewable energy consumption and unemployment in the Moroccan economy was explored by authors [9]. In the aftermath of the 2008 financial crisis, the concept of the "Green New Deal" gained prominence, emphasizing the integration of environmental measures and strategies within the recovery plans of various nations to spur economic growth. This paper aims to underscore the benefits of implementing green economic recovery policies on employment in Morocco, particularly within the renewable energy sector. The causal relationship between renewable energy consumption and unemployment was investigated utilizing the VAR model, Johansen's cointegration test, and the Granger causality test spanning from 1990 to 2017. The results indicate a causal linkage from renewable energy consumption to unemployment. Essentially, the renewable energy sector holds the potential to contribute to the alleviation of unemployment rates in Morocco. Consequently, investments in this sector could be pursued to generate employment opportunities, especially in the aftermath of the significant job losses caused by the COVID-19 pandemic. Further research indicates that there is a connection between the Share of Energy from Renewable Sources and unemployment, which can be either positive or negative. The authors of [10] utilized a cointegration test, which accommodates structural breaks that do not impact the test's accuracy in terms of the number, location, and form, to explore the long-term association between unemployment rates and renewable energy consumption in selected countries within the Organisation for Economic Co-operation and Development (OECD). The outcomes indicate a cointegration relationship between the variables for Australia, Austria, Chile, France, Germany, Japan, Mexico, Portugal, Spain, and the United States. The findings suggest that renewable energy consumption has a positive impact on unemployment rates in Austria, Portugal, and Spain, while it exerts a negative influence on unemployment rates in Australia, Chile, France, Germany, and Japan.

Our expectations for our study are focused on uncovering details regarding the relationship between the Share of Energy from Renewable Sources and moderate unemployment in Eurozone countries from 2006 to 2020. We anticipate that our results will provide further understanding of this relationship within a specific macroeconomic context and enable us to formulate recommendations for policies that could promote the utilization of renewable energy while also mitigating unemployment rates in the Eurozone.

These findings are crucial for our study, which aims to assess how these relationships differ within the context of the Eurozone from 2006 to 2020, and to gain a comprehensive understanding of the factors influencing the adoption of renewable energy in the region.

2.3. Relationship between Share of Renewable Energy and Financial Development

Researchers delved into the relationship between renewable energy and financial development. Reference [11] emphasized the enhanced energy efficiency and operational efficiency of businesses following financial development, leading to a reduction in energy consumption and subsequent decrease in CO_2 emissions. Additionally, [12] highlighted the fact that financial development has opened avenues for the adoption of modern, environmentally friendly technologies.

We expect our study to confirm this relationship, focusing on how financial development can support more efficient utilization of renewable energy sources and thereby reduce CO_2 emissions. Our work will concentrate on specific factors such as investments in energy-efficient technologies and the influence of the financial sector on promoting renewable energy sources. We anticipate that our results will provide recommendations for policies and practices that could support the development of renewable energy sources in an effort to achieve environmental and economic goals.

2.4. Relationship between Share of Renewable Energy and Inflation

Within existing studies, for example [13–15], the relationship between the Share of Energy from Renewable Sources and inflation is actively explored, emphasizing an analytical perspective on economic and energy interdependencies. The objective of the research outlined in [13] was to investigate the correlation between the utilization of renewable energy, the exchange rate, and the inflation rate through the application of the ARDL model. ECM findings reveal a long-term bidirectional association between the exchange rate and renewable energy in Brazil, indicating that the exchange rate affects the use of renewable energy, and vice versa. In the long term, inflation also influences renewable energy and the exchange rate. The rate of adjustment to equilibrium is below 50%, suggesting a prolonged adjustment to long-run equilibrium. In the short term, it is observed that the use of renewable energy significantly negatively impacts the exchange rate, indicating that an increase in renewable energy use substantially appreciates the exchange rate. Long-term results show that the use of renewable energy negatively affects the exchange rate (appreciation), while inflation and the exchange rate significantly positively influence the use of renewable energy. Therefore, promoting renewable energy not only contributes to reducing CO_2 emissions, but also supports the strengthening of the currency. The authors of reference [14] utilized sophisticated econometric approaches for their practical examination. The results obtained from fully modified least squares, dynamic least squares, and robust canonical cointegrating regressions indicate an inverse relationship between alternative energy sources, government expenditures, and inflation. Conversely, there is a positive correlation observed between economic growth and environmental quality in Germany spanning the years 1971 to 2016. The 2022 energy crisis had a notable impact on inflation, with the literature suggesting that a higher proportion of renewable energy sources could enhance economic resilience against external price shocks. The objective of the research conducted in [15] is to assess the correlation between the proportion of renewables in energy production and the Harmonized Index of Consumer Prices, as well as core inflation levels among EU countries during the crisis year of 2022. Through the utilization of regression techniques, cluster analysis, and dispersion measures, the investigation unveiled a statistically noteworthy relationship among these variables in 2022. A 1 percentage point increase in the share of renewables corresponded to a 0.13 percentage point decrease in HICP and a 0.1 percentage point decrease in core inflation. The "Wind" and "Solar" categories held the most significance in the multiple regression equation. Additionally, countries with a similar energy mix in 2022 exhibited comparable inflation rates, justifying the promotion of renewable energy for both environmental and economic benefits.

Our study focuses on evaluating the relationship between the share of renewable energy and inflation in Eurozone countries from 2006 to 2020. We expect that the results of our study will confirm the positive impact of renewable energy on reducing inflation within the Eurozone. We anticipate that an increase in the share of renewable energy will be accompanied by a decrease in inflation indicators, which should have beneficial effects on economic stability and environmental indicators in the region. Additionally, we expect that the results of our study will support the need to increase investments in renewable energy sources and strengthen policies supporting renewable resources for economic and environmental sustainability.

2.5. Relationship between Share of Renewable Energy and Government Effectiveness

Other studies [16,17] have delved into assessing government effectiveness in the country and the Share of Energy from Renewable Sources. Utilizing panel data encompassing 50 US states spanning from 1991 to 2007, study [16] employed a model integrating state Fixed Effects and state-specific time trends to assess the influence of state policies on the adoption of various emerging renewable electricity sources, including wind, biomass, geothermal, and solar photovoltaic systems. The findings indicated that Renewable Portfolio Standards, whether incorporating capacity or sales requirements, significantly influenced the adoption of all types of renewables. However, the impact varied depending

on the specific renewable source: it was negative for combined renewables, wind, and biomass, while positive for geothermal and solar. Moreover, the study found that clean energy funds and mandatory green power options generally facilitated the adoption of all types of renewables. Conversely, voluntary Renewable Portfolio Standards and state green power purchasing programs were deemed ineffective in enhancing the adoption of any type of renewable source. The findings of study [17] indicate that in cases where a developing nation embraces democracy and/or adopts a financial incentive policy for renewable energy, the influence of renewable energy Official Development Assistance (ODA) on the generation of renewable electricity is notably positive. This implies that relying solely on renewable energy ODA is insufficient for a substantial increase in renewable electricity generation in developing countries.

We expect that our study will bring findings that will place a strong emphasis on the relationship between the Share of Energy from Renewable Sources and government effectiveness. We aim to focus on how these relationships differ in the context of Eurozone countries from 2006 to 2020. The main objectives of our work are to assess the impact of macroeconomic factors on the adoption of renewable energy in the Eurozone and to gain a comprehensive understanding of the factors influencing this process.

Our study will also analyze the impact of various policies and measures on the adoption of renewable energy sources in the European Union, with an emphasis on government effectiveness and the share of renewable energy. We anticipate that our recommendations will be aimed at improving policy frameworks and support for renewable energy sources, with the goal of promoting their sustainable adoption and contributing to environmental and economic development in Europe.

Subsequent studies [18,19] have explored the relationship between the level of corruption in a country and the share of renewable energy. Investigation [18] delves into the correlation between corruption control and energy efficiency across 60 countries, segmented by income categories: lower middle, upper middle, and high. The study utilized a panel methodology spanning from 2000 to 2017. Given the confirmed cross-sectional dependence among the tested equations, unit root tests and the augmented mean group estimator were employed to address this issue. The overall findings suggest that lower corruption levels are associated with higher energy efficiency across all income groups. Furthermore, the research indicates that in lower-middle-income and high-income economies, renewable energy exerts a detrimental influence on energy efficiency, whereas its impact is beneficial in middle-income economies. Additionally, the study identifies the existence of the Environmental Kuznets Curve (EKC) across all income group economies. Based on the results, the recommendation is for countries in all income groups to strengthen corruption control measures to improve energy efficiency. Research conducted in [19] investigates the interrelationships between economic growth, corruption, renewable energies, international trade, and carbon dioxide emissions by analyzing panel data spanning European countries from 1995 to 2015. Employing the panel fully modified least squares, panel dynamic least squares, and panel two-stage least squares estimator methods as econometric methodologies, the study concludes that the variables are integrated I(1) when examined in first differences, as per the panel unit root test. The corruption index and economic growth significantly contribute to carbon dioxide emissions, while renewable energies and international trade play a role in mitigating climate change and enhancing environmental quality, as indicated by the cointegration of these variables in the long run.

These findings suggest that corruption control measures are crucial for improving energy efficiency.

Additionally, they highlight the importance of renewable energies and international trade in mitigating climate change and enhancing environmental quality.

In our study, we aim to assess how the level of corruption influences the Share of Energy from Renewable Sources in Eurozone countries from 2006 to 2020. We expect to find a similar pattern where lower corruption levels are associated with a higher proportion of renewable energy, indicating the importance of anti-corruption measures for sustainable en-

ergy development. Additionally, we anticipate that renewable energy will play a significant role in reducing carbon emissions and enhancing environmental quality in the Eurozone.

2.6. Renewable Energy and Eurozone Macroeconomics

Our study seeks to fill gaps in the existing literature by providing empirical evidence on the relationship between the Share of Energy from Renewable Sources and key macroeconomic variables in Eurozone countries from 2006 to 2020. While previous studies have explored similar relationships in various contexts, there is a lack of research specifically focusing on Eurozone countries over this time period. Therefore, our study aims to contribute to the understanding of how macroeconomic factors influence the adoption of renewable energy within the Eurozone.

Additionally, our study extends the existing literature by examining a comprehensive set of macroeconomic variables, including GDP per capita, unemployment rate, the Financial Development Index, inflation, government effectiveness, and Control of Corruption, in relation to the share of renewable energy. By analyzing these variables collectively, we aim to provide a more holistic understanding of the factors driving renewable energy adoption in the Eurozone.

Furthermore, our research contributes to the literature by employing the Fully Modified Ordinary Least Squares method, which allows for the robust estimation of long-run relationships between variables, while accounting for potential endogeneity issues. This methodological approach enhances the reliability and validity of our findings, addressing limitations identified in previous studies that may have relied on less sophisticated econometric techniques.

Overall, by addressing these research gaps and employing rigorous methodology, our study provides valuable insights into the dynamics of renewable energy adoption in the Eurozone and contributes to the broader literature on the intersection of macroeconomics and sustainable energy development.

3. Materials and Methods

This section of the article describes the manner in which we conducted our analysis of the impact of macroeconomic variables on the share of renewable energy in Eurozone countries and obtained the necessary data for this research.

In our paper, a panel data estimation method (FMOLS—Fully Modified Ordinary Least Squares with Fixed Effects) is employed to examine the correlation between macroeconomic factors and Share of Energy from Renewable Sources. This model allows for the incorporation of unique distinctions among Eurozone countries and, at the same time, tackles issues related to endogeneity and autocorrelation in the dataset. Our dataset comprises 19 countries within the Eurozone over the period from 2006 to 2020. The list of selected Eurozone countries is in Table 1.

Table 1. The list of selected Eurozone countries.

Countries	Codes	Countries	Codes
Austria	AUT	Latvia	LVA
Belgium	BEL	Lithuania	LTU
Cyprus	CYP	Luxemburg	LUX
Estonia	EST	Malta	MLT
Finland	FIN	The Netherlands	NLD
France	FRA	Portugal	PRT
Germany	DEU	Slovenia	SVN
Greece	GRC	Slovakia	SVK
Ireland	IRL	Spain	ESP
Italy	ITA		

It is important to note that the Economic and Monetary Union covers all EU countries, and 19 of the listed countries have adopted the euro as their sole currency, constituting the

Eurozone. This region is characterized by the replacement of national currencies with the common currency, the euro.

In the analysis, we used the following macroeconomic factors:

- Gross Domestic Product per capita (GDP);
- Unemployment rate (UNM);
- Financial Development Index (FDI);
- Inflation rate (INF);
- Government Effectiveness Index (GEF);
- Control of Corruption (CoC).

All the data used in our analysis are measured on an annual basis. The independent variables in our study included the mentioned macroeconomic factors. The dependent variable in our analysis is the Share of Energy from Renewable Sources (SEoRS). The data used for SEoRS are retrieved from the Eurostat database [20]. Datasets for GDP, as well as for UNM, INF, GEF, and CoC are retrieved from the World Bank World Development Indicators online database [21–24]. FDI data are retrieved from International Monetary Fund database [25].

To examine the relationship between the share of renewable energy and macroeconomic variables, we employed the following model:

$$SEoRS_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 UNM_{it} + \beta_3 FDI_{it} + \beta_4 INF_{it} + \beta_5 GEF_{it} + \beta_6 CoC_{it} + u_{it} \quad (1)$$

where i represents each country of euro area (i = 1, 2, 3, . . ., 19) and t denotes the time period (t = 2006–2020). β signifies the estimated coefficient for each variable. The term u_i accounts individual and time effects and the error term, for which the following equation applies:

$$u_{it} = \mu_{it} + \lambda_{it} + \nu_{it} \quad (2)$$

where μ_{it} represents the unobservable individual effect, λ_{it} denotes the unobservable time effect, and ν_{it} signifies the error term. Incorporating individual effects enables the consideration of unobservable discrepancies among individuals, which significantly impact our analysis but are not directly observable or quantifiable. Time effects assist in capturing trends or fluctuations over time, thereby providing valuable insights for our study. The comprehensive error term encompasses all other factors not explicitly addressed by individual or time effects [26].

Through the application of the FMOLS model, we can calculate the coefficients of chosen variables that may influence the Share of Energy from Renewable Sources. The findings from the study reveal the factors that exert a notable impact on the Share of Energy from Renewable Sources in Eurozone countries. Previous research did not delve into the influence of a set of factors on the Share of Energy from Renewable Sources. The advantages of this study lie in the examination of tested factors within Eurozone countries for the contemporary period up to 2020.

Expanding on the research question introduced in the opening, we outline both the null and alternative hypotheses that will be examined in our analysis in the provided Table 2.

Table 2. Null and alternative hypotheses of the research study.

	Hypotheses
Null	None of the examined macroeconomic factors exhibits a significant influence on the Share of Energy from Renewable Sources in the Eurozone.
Alternative	At least one of the considered macroeconomic factors demonstrates a substantial influence on the Share of Energy from Renewable Sources in the Eurozone.

If we reject the null hypothesis, the next research question will be: What impact does our estimated variable have on the dependent variable?

In our model we used the following parameters.

The dataset pertaining to the Share of Energy from Renewable Sources *($SEoRS_{it}$)* constitutes a crucial metric for monitoring advancements toward the renewable energy targets outlined in the Europe 2020 strategy, as implemented by Directive 2009/28/EC and the Fit for 55 strategy under the Green Deal, implemented by Directive (EU) 2018/2001. This dataset encompasses various renewable energy sources, each subject to specific normalization and inclusion criteria. Hydro energy, after normalization and the exclusion of pumping, is factored into the dataset. Wind energy undergoes a similar normalization process. Solar energy includes contributions from both solar photovoltaics and solar thermal power generation. The calculation process relies on data collected within the framework of Regulation (EC) No 1099/2008 on energy statistics. Additionally, specific supplementary data transmitted by national administrations to Eurostat complement the dataset, ensuring comprehensive coverage. This dataset is designated as a Sustainable Development Goal indicator, chosen to evaluate progress towards the objectives and targets outlined in the EU Sustainable Development Strategy. The data collection spans the entirety of the Member States of the European Union, with the time series commencing in the year 2004. The Share of Energy from Renewable Sources is calculated across four distinct indicators: Transport, Heating and Cooling, Electricity, and Overall RES share. The resultant indicator is expressed as a percentage. Basic data on energy quantities are initially recorded in fuel-specific units and subsequently converted to common energy units for the purpose of calculation [27].

Gross Domestic Product (GDP_{it}) at purchaser's prices is defined as the total sum of gross value added by all resident producers within the economy, encompassing any product taxes and excluding any subsidies not included in the value of the products. This measure is calculated without deductions for the depreciation of fabricated assets or the depletion and degradation of natural resources. The data are reported in current USD, with GDP figures converted from domestic currencies using official exchange rates for each individual year. When the official exchange rate fails to accurately reflect the rate employed in real foreign exchange transactions for specific countries, an alternative conversion factor is utilized. The periodicity of GDP measurement is annual, and the statistical concept and methodology behind its calculation involve summing the value added by all producers in the economy. Value added, in this context, denotes the value of gross output less the value of intermediate goods and services consumed in production, prior to accounting for consumption of fixed capital. The United Nations System of National Accounts outlines that value added can be evaluated either at basic prices, which exclude net taxes on products, or at producer prices, which include net taxes on products paid by producers but exclude sales or value-added taxes. Both assessments exclude separately invoiced transport charges by producers. Overall Gross Domestic Product (GDP) is calculated at purchaser prices, while the value added by industry is commonly measured at basic prices [28].

The unemployment rate, represented as UNM_{it}, indicates the proportion of the labor force that is without employment. Those categorized as unemployed are individuals of working age who are presently not employed, available for work, and have actively pursued employment opportunities. The uniform application of this definition enhances the international comparability of unemployment rate estimates in contrast to those derived from national definitions of unemployment. This metric is calculated as the number of unemployed individuals expressed as a percentage of the labor force and is subject to seasonal adjustments. The labor force encompasses the total number of unemployed individuals plus those currently employed. The International Labour Organization (ILO) is responsible for estimating this indicator [29]. The data utilized for this metric are sourced from the World Bank database [22].

FDI_{it} (Financial Development Index) is a metric within the category of financial factors influencing entrepreneurship. The data for this index are obtained from the Financial Development Index Database of the International Monetary Fund [25]. As per [30], the index is delineated as a "relative ranking of countries on the depth, access, and efficiency

of their financial institutions and financial markets". This aggregate index is derived from the combination of the Financial Institutions index and the Financial Markets index.

INF_{it}, denoting the inflation rate, is classified among financial factors, and the data for this metric are sourced from the World Bank database [23]. The annual inflation rate is calculated by comparing the price of the total basket in a specific month with its price in the same month one year prior. This basket symbolizes all the goods and services consumed by households throughout the year. Each item within this basket has an associated price, which can undergo changes over time [31].

GEF_{it} (Government Effectiveness Index) is a political factor incorporated into our analysis. Annual data for this index are obtained from the World Bank database [24]. The GEF assesses the quality of public services, civil service, policy formulation, policy implementation, and the government's commitment to enhancing or sustaining these attributes [32].

CoC_{it} (Control of Corruption) is an index indicating the level of corruption control within a country. The index is scored on a scale ranging from -2.5 to 2.5, where a score of -2.5 signifies weak Control of Corruption, and a score of 2.5 represents strong Control of Corruption [33]. These data are sourced from the World Bank database and are considered as one of the political factors influencing entrepreneurship [24].

In our analysis, we utilize the Full Modified Ordinary Least Squares (FMOLS) model as a robust framework to investigate relationships within our dataset. To determine the most appropriate model specification, whether Fixed Effects, Random Effects, or Pooled Effects, we conduct a series of diagnostic tests tailored for panel data analysis. We also conducted tests to check the normality and heteroskedasticity of the data.

Several tests are particularly relevant for this purpose, including:

1. Augmented Dickey–Fuller test: the Augmented Dickey–Fuller (ADF) test is a statistical test used to test the stationarity of time series data. Its primary purpose is to determine whether a given time series has roots that are stationary, which is important for the proper specification of econometric models. Through this test, we will test the following hypothesis [34]:

H1. *Time series contain one or more autoregressive components that are non-stationary.*

2. Jarque–Bera test: the Jarque–Bera test evaluates the normality of error terms, offering insights into the distributional assumptions of the model. The hypothesis for the Jarque–Bera test is as follows [35]:

H2. *The errors in the model follow a normal distribution.*

3. Breusch–Pagan test: the Breusch–Pagan test assesses the existence of heteroskedasticity (variance differences) in the error terms, Enabling the evaluation of assumptions concerning constant error variance. The hypothesis for the Breusch–Pagan test is stated as follows [36]:

H3. *There is no heteroskedasticity in the data (the error variance is constant).*

4. Hausman test: the Hausman test plays a vital role in selecting between Fixed Effects and Random Effects models. It investigates whether individual-specific effects (Fixed Effects) are correlated with the independent variables, assisting in determining the suitable model. The hypothesis for the Hausman test is formulated as follows [37]:

H4. *The individual-specific effects (Fixed Effects) are not correlated with the independent variables, indicating that Random Effects are more appropriate.*

These tests are crucial in informing our modeling choices, guaranteeing the selection of the most appropriate panel data approach according to our research inquiries and dataset attributes.

4. Results

Determining the appropriate path for analyzing results is a key aspect of scientific research. In this section of the article, we present and discuss the findings of our study on the relationship between the share of renewable energy and selected macroeconomic variables. Our analysis spans the period from 2006 to 2021 and employs advanced panel methods. First, we conducted an Augmented Dickey–Fuller (ADF) test to test the hypothesis H1 regarding the stationarity of the data. The results of the ADF test indicated that the data are stationary. The *p*-values for the individual time series of each variable were smaller than the printed *p*-value, or less than 0.05, respectively. This implies that we reject the hypothesis H1. To facilitate a comprehensive interpretation of the results, we conducted various diagnostic tests, and in this section, we focus on presenting and interpreting the key findings of our study. We evaluate the results in the context of model assumptions and conclusions that provide insights into the dynamics of the relationships between renewable energy and macroeconomic variables over time.

Table 3 displays the descriptive statistics of individual variables used in Equation (1). The table provides basic statistical indicators, such as the mean, median, maximum, minimum, standard deviation, skewness, and kurtosis, along with the number of observations for each variable. These statistics offer insights into the characteristics of the variables analyzed in our study.

Table 3. Descriptive statistics of the dependent variable and independent variables.

Descriptive Statistics	SEoRS	GDP	INF	FDI	GEF	CoC
Mean	16.86	37,043.20	1.72	0.58	1.21	1.11
Median	15.08	31,244.93	1.50	0.63	1.17	1.07
Maximum	43.94	123,678.70	15.40	0.90	2.24	2.45
Minimum	0.15	9230.71	−4.48	0.20	0.16	−0.19
Std. Dev.	10.68	22,698.20	1.96	0.20	0.46	0.68
Skewness	0.57	1.92	2.14	−0.54	−0.08	−0.02
Kurtosis	−0.62	4.30	11.29	−0.96	−0.60	−1.10
Observations	285	285	285	285	285	285

Source: own calculations.

For the SEoRS (Share of Energy from Renewable Sources), higher values indicate a greater proportion of renewable energy sources in the Eurozone, potentially reflecting higher sustainability in energy use. The average SEoRS value is 16.86, with a median of 15.08, indicating a moderate level of renewable energy utilization.

Regarding GDP (Gross Domestic Product), higher values are associated with greater economic prosperity, which can support investments in renewable energy. The average GDP value in our dataset is 37,043.20, with a median of 31,244.93.

The inflation rate (INF) is an important economic indicator, with higher values potentially indicating significant price fluctuations that may impact financial stability and investments in renewable energy. The average inflation rate is 1.72, with a median of 1.50.

The Financial Development Index (FDI) reflects the accessibility of financing for renewable energy projects, with higher values suggesting easier access to financing. The average FDI value is 0.58, with a median of 0.63.

Government Effectiveness (GEF) and Control of Corruption (CoC) are crucial for the functioning of governments and the level of corruption, which can impact investments in renewable energy. The average GEF value is 1.21, with a median of 1.17, indicating relatively effective governance. The average CoC value is 1.11, with a median of 1.07, suggesting a moderate level of Control of Corruption.

These statistics provide a snapshot of the variables under consideration and their distribution within the dataset, offering valuable insights into the economic and governance factors influencing renewable energy adoption in the Eurozone.

Table 4 displays the outcomes of several crucial diagnostic tests that were conducted to assess the validity and reliability of the analytical model. These tests serve to provide deeper insights into the underlying assumptions and characteristics of the model.

Table 4. Results of key diagnostic tests.

Jarque–Bera Test	
p-value	4.8359
Breusch–Pagan Test	
p-value	0.6845
Hausman Test	
Chi-square Statistic	33.5641
Chi-Square Statistic Probability	0.0000

Source: own calculations.

Starting with the *p*-value of the Jarque–Bera test (4.8359), this statistic offers valuable information regarding the normality of the model's error terms. A higher *p*-value indicates that we lack sufficient evidence to reject the null hypothesis (H2) of a normal distribution of errors. Essentially, if this *p*-value exceeds the chosen significance level, it suggests that the errors in our model follow a normal distribution, which is an essential assumption for many statistical analyses.

Moving on to the Breusch–Pagan test, its corresponding *p*-value (0.6845) helps us evaluate the presence of heteroskedasticity, or unequal variance, in the error terms. Similar to the Jarque–Bera test, a higher *p*-value here implies that we do not have enough evidence to reject the null hypothesis (H3) of constant error variance. This means that our model's error terms exhibit consistent variability across the data, reinforcing the reliability of our results.

Considering the Hausman test shows a strikingly low *p*-value of 0.000, we are provided with compelling evidence to reject the null hypothesis (H4) that individual effects are uncorrelated with the chosen independent variables. This result indicates a strong correlation between individual effects and the independent variables in our model. Consequently, it suggests that employing a model with Fixed Effects would be more appropriate, as individual effects significantly influence the behavior of the independent variables.

These diagnostic tests collectively support the suitability of the model described in Equation (1) for examining the relationship between the dependent variable and the chosen independent macroeconomic variables. The results in Table 4 not only present the *p*-values of these tests but also offer deeper interpretations of their implications. The Jarque–Bera test assesses the normality assumption, the Breusch–Pagan test evaluates heteroskedasticity, and the Hausman test provides insights into the correlation of individual effects with the chosen independent variables.

In conclusion, the outcomes of these diagnostic tests, detailed in Table 4, underscore the accuracy and robustness of our analytical model. They provide a comprehensive validation of the model's assumptions, strengthening our confidence in the reliability of the results presented.

Upon reviewing Table 5, it is apparent that all variables exhibit statistical significance, offering valuable insights into their impact on the dependent variable. The estimated coefficients in the second column elucidate the expected effects of each independent variable on the dependent variable, "Share of Energy from Renewable Sources".

Table 5. Results of model estimations.

Variable	Coefficient	Standard Error	Probability
Gross Domestic Product per capita	0.0002	6×10^{-5}	0.0021 ***
Unemployment rate	−0.1882	0.0773	0.0156 **
Financial Development Index	−20.4925	5.1536	0.0001 ***
Inflation rate	−1.1435	0.1198	0.0000 ***
Government Effectiveness Index	−3.1476	1.6508	0.0577 *
Control of Corruption Index	−4.7702	1.5083	0.0018 ***
R-squared		0.946409	

Note: "*" denotes statistical significance at the 10% level of significance (90% confidence interval; "**" denotes statistical significance at the 1% level of significance (99% confidence interval); "***" denotes statistical significance at the 0.1% level of significance (99.9% confidence interval). Source: own calculations.

The Gross Domestic Product per capita (GDP) demonstrates a positive relationship, with an estimated coefficient of 0.0002. This suggests that an increase in GDP per capita leads to a corresponding increase in the share of energy sourced from renewables. Conversely, the unemployment rate displays a negative relationship, indicated by its estimated coefficient of −0.1882. Higher unemployment rates are associated with a decrease in the share of renewable energy.

The Financial Development Index (FDI) shows a negative relationship with an estimated coefficient of −20.4925. This implies that higher values of FDI are linked to a reduction in the share of renewable energy. Similarly, the inflation rate exhibits a negative relationship, as indicated by its estimated coefficient of −1.1435. An increase in the inflation rate is correlated with a decrease in the share of renewable energy.

The Government Effectiveness Index (GEI) also presents a negative relationship, with an estimated coefficient of −3.1476. This suggests that a higher Government Effectiveness Index corresponds to a diminished share of renewable energy. Finally, the Control of Corruption Index (CoC) displays a negative relationship, denoted by its estimated coefficient of −4.7702. Improved Control of Corruption leads to a reduction in the Share of Energy from Renewable Sources.

These coefficient estimates provide valuable insights into the nuanced relationships between macroeconomic factors and the share of renewable energy. They collectively enhance our understanding, shedding light on the implications of each variable for ecological sustainability and economic growth in European countries.

Moving to the third column of Table 5, we encounter the standard errors, which signify the variability in the estimated coefficients. Lower standard errors indicate more precise estimates, while higher standard errors suggest greater uncertainty. Here, the standard errors of individual variables range from 6×10^{-5} to 5.1536, indicating reasonably accurate estimates.

In the last column, the probabilities associated with each estimated coefficient are denoted by symbols. The "*" symbol indicates statistical significance at various levels. The Government Effectiveness Index achieves significance at the 10% level, while the unemployment rate is significant at the 1% level. The Gross Domestic Product per capita, the Financial Development Index, inflation rate, and Control of Corruption Index all exhibit statistical significance at the 0.1% level.

In the final row of Table 5, the R-squared value is reported as 0.946409, indicating that the model explains approximately 95% of the variability in the dependent variable explained collectively by the independent variables. R-squared serves as a measure of the model's strength in explaining the variation in the dependent variable, presented on a convenient 0–100% scale.

Table 5 provides a comprehensive overview of the model estimations, highlighting the significance of each variable, the precision of the estimates, and the overall explanatory power of the model in understanding the dynamics of renewable energy shares in European countries.

The results of the analysis clearly confirmed the statistical significance of all observed variables, with the obtained coefficient estimates providing a detailed insight into the interrelationships among macroeconomic factors and the share of renewable energy. These findings enhance our ability to interpret and predict the impacts of individual variables on environmental sustainability and economic growth in European countries.

5. Discussion

In the chapter, we discuss the interpretation of results, their relation to the existing literature, and their contribution to the given issue.

In our research, we focused on testing the potential relationship between the dependent variable "Share of Energy from Renewable Sources" and several independent macroeconomic variables. We conducted the analysis using the FMOLS method on data related to Eurozone countries from 2006 to 2020. Based on our analysis, we rejected the null hypothesis stating that "None of the examined macroeconomic factors exhibits a significant influence on the Share of Energy from Renewable Sources in the Eurozone". Instead, we confirmed the alternative hypothesis: "At least one of the considered macroeconomic factors demonstrates a substantial influence on the Share of Energy from Renewable Sources in the Eurozone". Furthermore, we investigated the specific relationship between the dependent variable and individual independent variables.

In our study, a positive relationship between the Gross Domestic Product per capita (GDP) and the Share of Energy from Renewable Sources was observed (coefficient: 0.0002). This indicates that increasing GDP per capita positively influences the use of renewable energy. Comparing these results with existing research [6], a study focusing on European Union countries found a positive but minimal impact of GDP per capita on renewable energy sources (RES) in electricity (2007–2017). In our study, we identified a positive relationship between the Gross Domestic Product per capita (GDP) and the Share of Energy from Renewable Sources, similar to findings in the mentioned studies. The coefficient of 0.0002 suggests that increasing GDP per capita has a positive impact on the utilization of renewable energy. This aligns with the results of the study on European Union countries, which found a positive but minimal impact of GDP per capita on renewable energy sources in electricity during the period 2007–2017. In summary, our study's positive correlation between GDP per capita and renewable energy use is consistent with similar findings in the literature, emphasizing the role of economic development in promoting renewable energy adoption.

Our findings indicate that the unemployment rate exhibits a negative relationship, as evidenced by its estimated coefficient of -0.1882. A higher unemployment rate is associated with a decrease in the share of energy derived from renewable sources (SEoRS). This result contrasts with some other studies [8], where a positive relationship between SeoRS and unemployment is mentioned. Other outcomes suggest a possible positive or negative relationship between these variables [10]. Our findings suggest that results in this area can be diverse and depend on specific study conditions.

Our results demonstrate a negative relationship between the Financial Development Index (FDI) and the share of renewable energy, as indicated by the estimated coefficient of -20.4925. This aligns with the outcomes of existing studies on the relationship between renewable energy and financial development. Researchers, such as the authors of [11,12], have emphasized the positive impact of economic and financial development on environmental sustainability. They noted that higher economic and financial development leads to enhanced energy efficiency, operational efficiency, and the adoption of modern, environmentally friendly technologies, ultimately contributing to a reduction in energy consumption and CO_2 emissions.

Our study finds that, similar to existing research, the relationship between the Share of Energy from Renewable Sources and inflation is examined in our case. Our analysis indicates that the increasing inflation rate negatively influences the Share of Energy from

Renewable Sources. These findings align with the results of studies that focused on the relationship between renewable energy, inflation, and other economic variables [14,15].

Specifically, our findings reveal a negative correlation between the Government Effectiveness Index (GEI) and the share of renewable energy. This suggests that higher government effectiveness is associated with a reduced proportion of renewable energy. In comparison, other studies indicate a positive relationship, emphasizing the complex nature of these interactions [17].

In conjunction with existing research, particularly studies [18,19], we further explore the relationship between the Share of Energy from Renewable Sources (SEoRS) and the Control of Corruption Index (CoC). Reference [18] shows the results of an empirical investigation into the correlation between corruption control and energy efficiency across countries of different income categories, revealing that lower corruption levels are associated with higher energy efficiency. Reference [19] examined the connections among economic growth, corruption, renewable energies, international trade, and carbon dioxide emissions, finding significant contributions of corruption and economic growth to carbon dioxide emissions, while renewable energies and international trade play a role in mitigating climate change. In contrast, our results indicate a negative relationship between the Control of Corruption Index and the Share of Energy from Renewable Sources. Specifically, improved Control of Corruption is associated with a reduction in the proportion of energy sourced from renewable channels. These findings contribute to a more comprehensive understanding of the intricate interplay between corruption control, renewable energy utilization, and their implications for ecological sustainability and economic growth in European countries.

In the discussion section of our analysis focusing on the relationship between the Share of Energy from Renewable Sources and macroeconomic variables in Eurozone countries, we have concluded that all estimated parameters of the variables are statistically significant. Our findings provide evidence of a significant relationship between these variables, offering a deeper understanding of the dynamics of renewable energy utilization within the context of macroeconomic stability.

It is crucial to emphasize that we have introduced a novel approach to the existing literature by exclusively focusing on macroeconomic variables within Eurozone countries. This combination of factors represents a new contribution, as similar analyses in this specific area have been limited.

Our study thus paves the way for a more profound comprehension of the relationship between the share of renewable energy and macroeconomic indicators in the Eurozone. Simultaneously, it underscores the importance of monitoring and maintaining macroeconomic indicators at acceptable levels while advocating for an increase in the share of renewable energy. Our work supports the significance of policies aimed at sustainable development and energy transformation within European countries, offering a comprehensive perspective on these issues within the Eurozone context.

6. Conclusions

In conclusion, we identified several key findings. Firstly, based on our analysis, we rejected the null hypothesis stating that "None of the examined macroeconomic factors exhibits a significant influence on the Share of Energy from Renewable Sources in the Eurozone". Instead, we confirmed the alternative hypothesis: "At least one of the considered macroeconomic factors demonstrates a substantial influence on the Share of Energy from Renewable Sources in the Eurozone". Secondly, a positive relationship was observed between the Gross Domestic Product per capita (GDP) and the Share of Energy from Renewable Sources, indicating that increasing GDP per capita positively influences the use of renewable energy. These findings carry significant policy implications that could support initiatives promoting sustainable development and transitioning to renewable energy in European countries.

Given the positive correlation between GDP per capita and the share of renewable energy, policymakers should focus on fostering economic growth as a means to enhance

the adoption of renewable energy sources. Policies aimed at boosting GDP per capita, such as investment in infrastructure and innovation, could yield dual benefits of economic prosperity and sustainable energy use.

With the confirmed influence of macroeconomic factors on renewable energy adoption, there is a clear need for increased investment in renewable energy infrastructure. Governments and stakeholders should prioritize funding and incentives for the development and expansion of renewable energy technologies to capitalize on the observed positive relationship.

Furthermore, we identified a negative relationship between the unemployment rate and the share of renewable energy, as well as a negative relationship between the Financial Development Index and the share of renewable energy. These findings underscore the importance of effective employment and financial development policies in supporting sustainable energy use.

The negative correlation between the unemployment rate and the share of renewable energy suggests that effective employment policies can contribute to the transition to sustainable energy. Policymakers should consider initiatives that create jobs in the renewable energy sector, such as training programs and incentives for renewable energy businesses.

The negative relationship between the Financial Development Index and the share of renewable energy indicates the importance of a supportive financial sector. Policymakers should work towards creating an environment that facilitates access to financing for renewable energy projects, including favorable lending terms and financial incentives for investments in green technologies.

As our analysis focused on the Eurozone, there is an opportunity for cross-border collaboration to promote renewable energy adoption. European countries can share best practices, harmonize policies, and collaborate on transnational renewable energy projects to maximize the benefits of sustainable energy across the region.

By considering these policy implications, policymakers can take concrete steps towards advancing sustainable development and achieving a greener, more resilient energy future for European countries. However, it is important to emphasize that our study has certain limitations, which may influence the interpretation of our results and the value of our findings. One of these limitations is the narrow scope of analysis, which focused exclusively on Eurozone countries and macroeconomic variables. This limited framework could have restricted our ability to gain a comprehensive and global view of the factors influencing the adoption of renewable energy. For instance, there is a possibility that within a broader international set of countries, we could identify additional relevant factors that might impact the adoption of renewable energy. This means that our findings are confined to European conditions and may not be applicable in a global context.

Additionally, while we utilize panel data, we are looking at the Eurozone countries as a whole. We do not examine the impact of individual macroeconomic variables on the share of renewable energy in each country separately.

The impact of these limitations on our results should be taken into consideration when interpreting our findings. Despite these limitations, our study contributes to expanding knowledge about the adoption of renewable energy by conducting a detailed examination of the role of macroeconomic variables in the context of the Eurozone. Identifying significant relationships between these variables offers valuable guidance for policymakers and stakeholders aiming to promote sustainable development and energy transformation in European countries.

Given these limitations and their potential impact on the results, future research should consider the following steps. One step could be to broaden the scope of analysis to include additional countries outside the Eurozone and more factors that might influence the adoption of renewable energy. This would enable a more comprehensive and global perspective on this issue. Another step could be to compare different econometric methods and their application to our dataset, which could provide more robust and reliable results.

At the same time, it would be beneficial to focus on other aspects of the impact of macroeconomic factors on the adoption of renewable energy, such as political and legislative measures, environmental and social cohesion, and so on. These factors could offer a deeper insight into the overall context of the sustainable energy industry.

In summary, our work represents a step towards better understanding the factors influencing the adoption of renewable energy in the Eurozone. Despite the limitations, our study has value in providing guidance for policymakers and stakeholders in supporting sustainable development and the transformation of the energy sector.

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