sustainability

MDPI

Article

How Renewable Energy and CO_2 Emissions Contribute to Economic Growth, and Sustainability—An Extensive Analysis

Mara Madaleno [1,*] and Manuel Carlos Nogueira [2]

[1] GOVCOPP—Research Unit in Governance, Competitiveness and Public Policy, Department of Economics, Management, Industrial Engineering and Tourism (DEGEIT), University of Aveiro, 3810-193 Aveiro, Portugal
[2] GOVCOPP—Research Unit in Governance, Competitiveness and Public Policy, ISPGAYA—Higher Polytechnic Institute of Gaya, University of Aveiro, Avenida dos Descobrimentos, 303, Santa Marinha, 4400-103 Vila Nova de Gaia, Portugal
* Correspondence: maramadaleno@ua.pt

Abstract: Using energy efficiently is crucial for economic development and sustainability. However, excessive use of fossil fuels impedes sustainable economic growth, and the released emissions have a negative impact on the environment. Still, there is no consensus in the literature as to the side effects or even regarding the determinants used to assess this relationship. As such, this article explores the effects that CO_2 (carbon dioxide) emissions and renewable energy consumption have on economic growth, using fixed assets, human capital, research and development, foreign direct investment, labor force, and international trade as controls, on a sample of 27 EU (European Union) countries between 1994 and 2019. Four different methodologies were applied to the sample, namely ordinary least squares, fixed effects, random effects, and the generalized method of moments in first differences, allowing endogeneity to be accounted for. Results show that gross fixed capital, human development, and trade contribute positively to economic growth; however, even though these contributions increase due to renewable energy consumption, that increase occurs at the expense of more CO_2 emissions. This expense may be justified by the high dependency on fossil fuels in the EU 27 group. Policy implications are presented for policymakers, namely governments, in light of sustainability and climate change.

Keywords: renewable energy; economic growth; CO_2 emissions; human capital; investment; sustainability

check for updates

Citation: Madaleno, M.; Nogueira, M.C. How Renewable Energy and CO_2 Emissions Contribute to Economic Growth, and Sustainability—An Extensive Analysis. *Sustainability* **2023**, *15*, 4089. https://doi.org/10.3390/su15054089

Academic Editors: José Alberto Fuinhas, Matheus Koengkan and Renato Filipe de Barros Santiago

Received: 30 January 2023
Revised: 19 February 2023
Accepted: 21 February 2023
Published: 23 February 2023

1. Introduction

Renewable energy emits fewer (or no) greenhouse gases, and at the same time, countries need to ensure proper economic growth. Economic growth needs to be achieved sustainably, and ensuring lower pollution levels is necessary for climate change agreement goals to be met. At the same time, higher fossil fuel energy prices, increased inflation levels, higher living standards, and increased difficulties faced by families also justify a stronger use of renewable energy. By reviewing the existent literature between 2010 and 2021 [1], this study highlights that renewable energy does not hinder economic growth in either developed or developing countries.

Since [2] examines the relationship between renewable energy consumption and economic growth, many researchers have explored this link. However, no consensus has yet been reached. Despite recent efforts to conform with COP-27 (the 27th Conference of the Parties of the UNFCCC—United Nations Climate Change Conference) and increased energy prices due to the full-scale aggression of the Russian Federation against Ukraine, there are still doubts as to the real effects of renewables consumption on economic growth [3]. The quest for greener energy consumption emerged worldwide due to the related projections for fossil fuel depletion, turning the energy-led economic growth nexus into an interesting area of research to ensure a sustainable environment [4].

There are limited sources available for conventional energy, but that energy is highly necessary to create production levels that justify economic growth, even if the negative effects of the energy sources are far worse than the economic benefits [5]. This situation is forcing the world to move towards renewable energy consumption and production to decrease fossil-energy dependency [3,6,7]. Additionally, the current concerns about fossil fuels depletion are related to their frequent use and high consumption rates. Fossil fuels are also associated with greenhouse gas effects, which lead to global warming [2,4]. Meanwhile, green energy is naturally replenished and fosters sustainable development [7,8].

The present article intends to contribute to the debate about how CO_2 emissions and renewable consumption effect economic growth. Since there is no consensus in the literature, we intend to highlight the effects of both CO_2 emissions caused by the burning of fossil fuels and the consumption of renewable energies on economic growth of the 27 countries of the European Union in the period between 1994 and 2019. We added six variables to the analysis, which serve to control the results obtained, namely: investment in fixed assets (gross capital formation) as a percentage of GDP (Gross Domestic Product); research and development expenditure as a percentage of GDP; labor force participation; school tertiary enrollment to represent the level of human capital qualifications; foreign direct investment; and involvement in a country's international trade. As such, a broader spectrum of exogenous variables was included in the analysis, allowing us to reach further than the justifications that already exist in the literature. We assume a log–log model specification, with the estimated coefficients representing the constant elasticities. Thus, coefficients represent the percentage change in the dependent variable due to a percentage change in the explanatory variables. Moreover, both models, ignoring endogeneity and those variables which account for it, are used for estimations and robustness checks. Finally, a balanced panel dataset was composed. It is believed that, with more complete information, the paper results will contribute more efficiently to the contradictory findings that are currently present in the literature.

As pointed out by [1,3], we may group empirical literature about energy consumption and its impact on economic growth into positive and negative influences, but there is still no formal conclusion. The energy-led economic growth hypothesis points to an indispensable role of energy in economic growth [8]. However, results mentioning a negative impact of renewable energy consumption over economic growth also exist [9]. Based on these contradicting results, we intend to shed more light on the existing literature. Moreover, while current studies do explore the variables we include in our analysis, they are not explored jointly. This is true even though many of the existing empirical works are concentrated in individual countries or small groups of countries and present inconclusive results. Contradictory evidence could lead to ineffective policy definition and subsequent implementation. Therefore, this research manages to contribute to this ongoing debate and entice scholarly interest in the subject, focusing not on a specific country or small group of countries, but on the EU27 and while considering European energy policies that are being implemented. Trade openness and economic growth studies also demonstrate ambiguous results, with final reported impacts that are dependent on economic conditions. Positive effects are found by [10], whereas, considering Indonesia, [11] points to an inverse relationship. Based on these inconclusive results, the joint energy policies being implemented in EU27, increased energy prices, COP 27 decisions, and joint climate change efforts, the present work tries to shed new light on the CO_2 emissions–renewables–growth nexus, accounting for endogeneity problems empirically. In the literature, we find the work of [12], whose results suggest that trade openness and renewable energy use promote economic growth by applying FMOLS (full modified ordinary least squares) and DOLS (dynamic ordinary least squares) econometric techniques in EU 28 countries. Our work is different from existing studies in three aspects at least: we use different methodologies, extended the period of analysis, and also, by including other control variables, we are able to explain the relationship between CO_2 emissions–growth–renewables.

The rest of the article is presented as follows. Section 2 presents a brief review of the recent literature on the topic. Section 3 presents the data, variables, main statistics, and correlations, highlighting the relevant results. Section 4 provides the empirical findings, whereas in Section 5 we discuss the results and provide some policy implications. Finally, Section 6 concludes this work.

2. Literature Review

For OECD (Organisation for Economic Co-operation and Development) countries and using panel data methodology, starting from a Cobb–Douglas type production function, [13] concluded that there is a long-term equilibrium relationship between real GDP and GDP per capita, and from the ratio of renewable energy consumption to total energy consumption, investment, employment, and R&D (research and development), thus confirming the importance of these variables in economic growth. For a wide range of countries, using Multivariate Panel Data Analysis, [14], concluded that there is a statistically significant relationship between the production and consumption of renewable energy, both for developed and developing economies, suggesting that renewable energy can be an important source of sustainable economic growth in the future.

By verifying the relationship between renewable energy consumption and economic growth for a set of 103 countries between 1995 and 2015, [15] found that, for OECD countries, there is a positive and significant relationship between this consumption and economic growth. For non-OECD countries, a positive and significant relationship starts to occur when these countries intensify the use of renewable energies. For low renewable energy consumption, the effect on economic growth is negative. In other words, the negative effect of consumption on economic growth in the early stages of renewable energies can be compensated for in the long term, when these countries start to intensify the level of consumption of renewable energies. For [15] the use of the variable renewable energy consumption divided by total energy consumption is also preferable to the use of the variable renewable energy production with respect to total energy production, because renewable energy production prices differ depending on the specific alternative source used.

In Ghana, a country considered blessed for the use of renewable energy, the reality is that consumption of this type of energy has a significant and positive bidirectional relationship with economic growth. The variables trade, investment, and FDI (foreign direct investment) also have positive and significant impacts on economic growth. These results are verified in both the short and the long term [16]. The increased energy usage creates new jobs, and the labor force needs to respond to these demands [1]. Moving towards renewable energy leads to economic development beyond economic growth by reducing carbon emissions [17,18].

Considering energy consumption as the backbone of economic growth and studying the effect of consumption of bioenergy from biomass as an alternative and sustainable source for energy production (considering the hypothesis of economic growth within a production function type Cobb–Douglas), [19] found that renewable energy consumption from biomass has a positive and significant impact on economic growth in the countries of the European Union. These authors also found that this relationship is stable in the long term. Therefore, fossil fuels are a considerable source of carbon emissions and environmental degradation [1]. Using non-renewable energy sources enhances economic growth but increases the dilemma in policy priorities. Should countries promote economic growth, or bet on renewables and promote sustainable growth? It should be borne in mind that renewable sources demand sophisticated energy technologies, an appropriate workforce, and gross fixed investment beyond R&D. Supplying energy from renewable sources is also time-consuming and costly, demanding balanced spending from governments to maintain economic growth and simultaneously enhance sustainable development by embracing the necessary climate change mitigation. Economic growth depends heavily on energy consumption [14,17]. In turn, energy consumption is highly responsible for greenhouse gas emissions, particularly CO_2 emissions [20].

Increased economic growth is positively correlated with increased pollution levels. Higher carbon emissions are associated with non-renewable energy consumption and globalization [21], and are also considered harmful to human health [22]. Research points out that R&D expenditure, international trade, technology, innovation, and trade-adjusted carbon emissions are suitable for environmental recovery, without impeding economic growth [23,24]. Thus, many studies claim that renewable energy is a good strategy for environmental sustainability [3]. Chang and Fang [25] confirm a positive association between renewable energy consumption and economic growth in BRICS (Brazil, Russia, India, China, and South Africa). Moshin et al. [8] found bi-directional causality in 25 Asian countries, and that renewable energy decreases both emissions and environmental degradation. For 29 European countries, [26] suggests that renewables enhance economic growth while reducing emissions. Results from [27] for 75 economies, from [28] for G7 countries (Canada, France, Germany, Italy, Japan, United Kingdom, and the United States), and from [15] for 103 world economies, point to mixed results depending on economic conditions faced by countries. Chen et al. [15] found a positive influence in developing and non-OECD countries when they exceed a certain threshold level; however, they found a negative influence whenever the countries used renewable energy below that threshold.

For G7 countries, [29] highlights that green growth decreases CO_2 emissions, as human capital is necessary to simultaneously achieve sustainable growth. As pointed out by [1], prior research uses essential and more sophisticated methodologies to examine emission levels and economic growth, energy structure, energy efficiency, financial development, technological development openness, and population. Few studies simultaneously examine CO_2 emissions, renewable energy consumption, economic growth, investment in fixed assets, human capital, R&D, labor force participation, foreign direct investment, and international trade, as we do in this study; we also consider a larger data span (1994–2019) for all EU 27 countries.

Fang et al. [30] measured the development of green economic growth, R&D, and green finance in the South Asian region between 2008 and 2020, suggesting that R&D reduces carbon emissions, allowing for a green economic recovery. They also conclude that, to minimize tiers of CO_2 emissions and technology spillovers, industrial structural change is needed, especially in developing economies. The findings of Hussain et al. [31] confirm that green technology enhances green growth, and that emissions harm green growth in high-GDP countries. Economies that adopt advanced technologies make productivity progress in the environment [32]. Grafström et al. [33] address the importance of government support for renewable energy R&D for 12 EU countries. Their findings defend the view that countries with less energy-import dependence and deregulated electricity markets receive less government R&D support. Topcu et al. [34] confirm that energy consumption, gross capital formation, urbanization, and natural resources have different impacts on GDP by income level.

Infrastructure investment is needed to meet renewable energy demands for human capital, labor force participation, gross capital formation, and the associated research and development required for sustainable economic growth; a positive association on these items is easier to observe in high-income countries [34]. Foreign direct investment increases when countries have sufficient natural resources or can manage the available resources more efficiently, decreasing their dependence on other countries. For the MENA region (countries situated in and around the Middle East and North Africa), [35] found that FDI plays a key role in promoting economic development by leading to beneficial impacts on environmental sustainability and economic growth. In a panel of 105 countries, FDI was found to aggravate CO_2 emissions, as did economic growth, industrialization, and trade openness [36]. Again, the impacts of different variables depend on the country's income level, making it relevant whether additional variables are included in the study, and verifying whether results from countries that have relatively high income growth, or are at least developed, apply in other countries.

Capital accumulation stimulates economic growth, and economic growth promotes physical capital stocks by proportionating capital investments [33,34]. Mahmood et al. [37] conclude that trade openness increases CO_2 emissions, whereas human capital mitigates emissions in Pakistan. However, [38] infers that, in China, increasing human capital leads to the escalation of emissions and environmental degradation, demonstrating that the Chinese economy is sustained through pollution-embedded trade. As mentioned by [39], education (as the basis for human capital) creates the necessary conditions for higher social welfare concerns, encouraging people to behave in a more environmentally friendly way through environmental-oriented behaviors [38]. Not many studies include this variable in the renewables–CO_2-emissions–growth nexus exploration, and the few studies that have been conducted have mixed results.

3. Data, Variables, Main Statistics, and Correlations

The sample used in this study comprises the period 1994–2019 for the 27 countries of the European Union. Since there are no missing observations, the panel is balanced with a total of 702 observations. The database was obtained through access to the World Development Indicators (WDI), which is the primary World Bank collection of development indicators and is compiled from officially recognized international sources.

Table 1 shows the variables used in the empirical analysis, their definitions, the objectives of each variable, and the unit. Except for GDP per capita which is expressed in USD, and CO_2 emissions expressed in tonnes per capita, all other variables are expressed in percentages. Table 2 shows the average of the same variables by country.

Table 1. Variables definition and data sources.

Variable Acronym	Definition	Objectives	Unit
$GDPpc_{it}$	Gross domestic product per capita, in the country i and year t (constant, 2015)	Achieving the growth of an economy	USD
CO_{2it}	CO_2 emissions, in the country i and year t	Quantify CO_2 emissions from burning fossil fuels	Tons per capita
REC_{it}	Renewable energy consumption in the country i and year t	Measure renewable energy consumption concerning final energy consumption	Percentage
GCF_{it}	Gross capital formation, in the country i and year t	Investments made in fixed assets concerning GDP	Percentage
$R\&D_{it}$	Research and development expenditure, in the country i and year t	Measuring investment in R&D concerning GDP	Percentage
LFP_{it}	Labor force participation, in the country i and year t	Amount of population providing labor for the production of goods and services	Percentage
ST_{it}	School tertiary enrollment, in country i and year t	Level of human capital qualifications	Percentage
FDI_{it}	Foreign direct investment, in country i and year t	Amount of foreign investment in a country	Percentage
$Trade_{it}$	International trade, in country i and year t	Involvement in a county's international trade	Percentage

Source: Authors' elaborations.

As we can see, for the period under review, the country with the highest average GDP per capita (constant, 2015) is Luxembourg (€99,152), with Bulgaria (€5592) as the country where this variable is the lowest. Between these two countries, there is an impressive disparity of €93557 in GDP per capita, which demonstrates the wide range of income in the EU. In terms of emissions of tons of CO_2 per capita, the lowest average is found in Latvia (3597) and the highest in Luxembourg (20,324). The most polluting country in the EU on average is the one with the highest level of per capita wealth. In terms of renewable energy consumption, the country with the highest average is Sweden (41,893), and Malta (2027) has the lowest average, even though this country has been intensifying its energy consumption from renewable sources in recent years. Other northern European countries such as Finland (34,133) and Latvia (36,125) also have high per capita energy consumption from renewable sources.

Table 2. Average of variables for each EU country (1994–2019).

Country	GDPpc	CO_2	REC	GCF	R&D	LFP	ST	FDI	Trade
Austria	41,204	8.055	28.970	24.693	2.462	59.708	66.872	2.175	92.095
Belgium	37,825	9.982	4.622	23.214	2.165	52.533	64.547	11.983	144.296
Bulgaria	5595	6.091	11.088	21.234	0.576	52.680	52.691	7.066	103.031
Croatia	11,036	4.277	28.752	22.703	0.906	49.025	47.452	3.516	80.031
Cyprus	23,866	6.883	5.936	20.754	0.403	62.521	40.771	64.014	125.181
Czechia	15,133	10.981	9.624	29.465	1.397	59.873	47.183	4.821	118.034
Denmark	50,666	9.045	19.124	21.287	2.587	64.054	69.437	2.382	90.163
Estonia	14,341	12.202	21.670	29.150	1.261	60.953	61.080	7.531	142.369
Finland	40,499	10.563	34.133	22.873	3.125	60.828	83.974	3.523	73.246
France	34,719	5.525	11.137	22.157	2.170	55.841	55.088	5.034	54.849
Germany	37,010	9.713	8.838	21.531	2.639	59.004	57.513	2.257	70.560
Greece	19,426	7.832	10.921	19.937	0.761	51.828	82.410	0.837	55.132
Hungary	10,843	5.114	9.692	24.754	1.055	51.390	48.631	10.578	136.160
Ireland	47,770	9.458	4.908	25.624	1.280	60.461	58.504	17.200	174.861
Italy	31,598	6.913	9.985	19.702	1.175	48.672	58.091	1.011	51.015
Latvia	10,724	3.597	36.125	26.425	0.513	59.214	64.411	3.874	100.841
Lithuania	10,780	3.801	20.547	21.140	0.780	58.963	64.819	3.347	117.211
Luxem.	99,152	20.324	5.802	19.984	1.436	55.904	13.357	17.631	283.791
Malta	19,298	5.661	2.027	22.431	0.463	51.221	35.014	73.541	261.071
Poland	9573	8.087	8.604	21.487	0.771	57.083	59.334	3.304	74.716
Portugal	18,848	5.245	24.245	21.921	1.063	60.183	55.761	3.554	69.749
Romania	6676	4.274	18.601	24.347	0.470	58.081	41.250	3.387	66.841
Slovakia	12,498	6.783	8.180	26.284	0.717	59.604	40.247	3.591	146.964
Slovenia	19,228	7.425	17.480	24.431	1.742	58.245	68.900	1.960	122.914
Spain	24,758	6.398	11.721	23.500	1.118	55.940	69.351	2.871	56.592
Sweden	45,214	5.267	41.893	22.881	3.328	66.521	66.614	4.530	80.731
TheNether.	42,151	9.937	3.595	21.224	1.900	63.565	63.804	18.124	129.922

Source: Authors' calculations.

In terms of average investment as a percentage of GDP, the country that invests the most is Czechia (29.465%), and the country that invests the least is Greece (19.936%). We can also see that in general terms, all countries have average investments between 20% and 30% of their GDP.

As regards average investment in terms of R&D as a percentage of GDP, it is highest in Sweden (3.328%) and lowest in Cyprus (0.403%). Finland (3.125%) and Germany (2.639%) also show high investment values in R&D as a percentage of GDP, but Romania (0.470%) and Bulgaria (0.576%) have few investments in R&D. Labor force participation is highest in Sweden (66.521%) and lowest in Italy (48.672%) and Croatia (49.025%), where more than half of the population aged over 15 who can be considered economically active do not participate in the labor force.

The gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of tertiary education. The average is higher in Finland (83.974%) and lower in Luxembourg (13.357%). Foreign direct investment as a percentage of GDP is highest in Malta (73.541%) and Cyprus (64.014%) and lowest in Greece (0.837%), Ireland and Luxembourg still show values around 17%. The degree of openness to the outside world in average terms is highest in Luxembourg (283.291%) and Malta (261.071%) and lowest in Italy (only 51.015%). We can also see in Table 2 that the economics of Spain, Greece, and France have a degree of openness to the outside, below 60%.

Table 3 contains the main descriptive statistics, namely the maximum and minimum values, means, and standard deviations of the variables used.

The highest GDP per capita value occur in Luxembourg in 2006 and the lowest in Bulgaria in 1999; meanwhile, CO_2 emissions were highest in Luxembourg in 1994 and lowest in Latvia in 2000. The variable renewable energy consumption assumes the maximum value in Sweden in 2019 and the minimum value in Malta for several years. Gross capital formation reaches its maximum value in Ireland in 2019 and its minimum value in Bulgaria in 1996.

In turn, expenditure on investment in research and development was higher in Sweden in 2000 and lower in Cyprus in 1997. Labor force participation variable was higher in 2019 in Sweden and the lowest value occurred in Croatia in 1995. School tertiary enrollment is highest in Greece in 2019 and lowest in Luxembourg in 1994.

Finally, foreign direct investment reached its peak in Malta in 2007, and in the same year, the minimum was verified in Luxembourg, while the trade variable reached its maximum value in Luxembourg in 2019 and the minimum value in Greece in 1994.

Table 3. Main descriptive statistics.

	Maximum	Minimum	Average	Std Deviation
GDPpc	112,417	3537	27,435	20,163
CO_2	26.829	2.927	7.7569	3.575
REC	52.880	0.010	15.490	1.600
GCF	54.955	1.157	23.152	4.556
R&D	3.873	0.203	1.417	0.882
LFP	73.360	36.211	57.554	5.284
ST	148.531	7.038	57.185	21.375
FDI	449.081	−57.532	10.395	34.669
Trade	377.842	36.163	111.941	60.145

Source: Authors' calculations. GDPpc—Gross domestic product per capita; CO_2—CO_2 emissions; REC—Renewable energy consumption; GCF—Gross capital formation; R&D—Research and development expenditure; LFP—Labor force participation; ST—School tertiary enrollment; FDI—Foreign direct investment; Trade—International trade.

Table 4 contains Pearson's correlation coefficients. To obtain accurate results from the empirical analysis, we also consider the problem of multicollinearity. The Pearson's correlation test, applied to our variables, showed that there is no multicollinearity between the variables considered, considering that we used the value of −0.80 or 0.80 as a limit, like other studies [40].

Table 4. Correlations.

	GDPpc	CO_2	REC	GCF	R&D	LFP	ST	FDI	Trade
GDPpc	-	0.6525	−0.0333	−0.1541	0.5443	0.2404	−0.0242	0.0890	0.4221
CO_2	-	-	−0.3595	0.0508	0.2405	0.1025	−0.2458	0.0573	0.3973
REC	-	-	-	0.0331	0.3817	0.2949	0.4470	−0.1973	−0.2681
GCF	-	-	-	-	−0.091	0.1007	0.1428	−0.0520	0.0077
R&D	-	-	-	-	-	0.3763	0.4215	−0.1408	−0.1227
LFP	-	-	-	-	-	-	0.1497	−0.1276	−0.2642
ST	-	-	-	-	-	-	-	−0.1276	−0.2642
FDI	-	-	-	-	-	-	-	-	0.3353
Trade	-	-	-	-	-	-	-	-	-

Source: Authors' calculations. GDPpc—Gross domestic product per capita; CO_2—CO_2 emissions; REC—Renewable energy consumption; GCF—Gross capital formation; R&D—Research and development expenditure; LFP—Labor force participation; ST—School tertiary enrollment; FDI—Foreign direct investment; Trade—International trade.

4. Empirical Analysis, Model Specification, and Estimation Methods

As we explained before, we use balanced panel data to estimate the model which seeks to explain the effects that CO_2 emissions caused by the burning of fossil fuels and the consumption of renewable energies have on the economic growth of the 27 countries of the European Union, in the period between 1994 and 2019. Additionally, we added six variables to the analysis, which serve to control the results obtained. We assumed a log–log model specification; therefore, the estimated coefficients represent the constant elasticities showing the percentage change in the dependent variable due to a percentage change in the explanatory variables. The model takes the following form:

$$\mathrm{lnGDPpc_{it}} = \alpha_i + \beta_1\,\mathrm{lnCO_{2it}} + \beta_2\,\mathrm{lnREC_{it}} + \beta_3\,\mathrm{lnGCF_{it}} + \beta_4\,\mathrm{lnR\&D_{it}} + \beta_5\,\mathrm{lnLFP_{it}} + \beta_6\,\mathrm{lnST_{it}} + \beta_7\,\mathrm{lnFDI_{it}} + \beta_8\,\mathrm{lnTrade_{it}} + u_{it} \quad (1)$$

Equation (1) regresses the lnGDP per capita as a function of the ln of CO_2 emissions, the ln of renewable energy consumption, and the ln of six control variables: gross capital formation; research and development expenditure; labor force participation; school tertiary enrollment; foreign direct investment; and international trade.

Three methods of estimation can be used to estimate Equation (1) with panel data. The simple OLS (Ordinary Least Squares) approach on the pooled model assumes no country and time-specific effects. However, this method of estimation is more appropriate to a set of homogeneous countries; this is not appropriate for our study since our sample includes both more and less advanced countries with different structures and levels of development. An alternative estimation approach that captures country-specific heterogeneity is the fixed effects (FE) model capturing the country-specific heterogeneity in the constant part (as it is different from country to country) as it is shown in Equation (1). This model can be estimated by the LSDV (least squares dummy variables) method, either assuming country-specific dummy variables or by the time-demeaned estimation approach [41]. Using the FE (fixed effects) method, an explicit hypothesis is made that fixed effects are not correlated with the explanatory variables, and FE estimates are not consistent under this condition. The third estimation method applied to panel data is the random effects (RE) approach, which considers that the country´s heterogeneity is not observable and captured in the error term. The estimation method used is GLS (generalized least squares) applied to the partially demeaned model [41]. Using this method, the hypothesis that the unobserved error term is not correlated with the explanatory variables is crucial to obtain unbiased and consistent estimates.

To decide which estimation method to perform (OLS, LSDV, or GLS) three statistical tests are normally used. The F-test tests the pooled model versus the FE model, the Breush–Pagan LM test tests the pooled model versus the RE model, and the Hausman test tests the RE model versus the FE model. Performing the three statistical tests, the FE model is the most appropriate specification to adopt (p-value of F-test = 0; p-value of the Breush–Pagan LM test = 0; p-value of the Hausman test = 1.55838×10^{-3}).

A very common problem in panel data is endogeneity, which is often not verified and corrected. As we can see in Table 5, the results of the Hausman Test show that several variables can be considered endogenous (p-value less than 0.05). In this case, the null hypothesis that there is no correlation with the error term is rejected, so the estimation approach using instrumental variables should be used to obtain consistent estimators, for example, by dynamizing the model [40], because in presence of endogeneity, the estimation may provide biased results.

According to [42–44], the inclusion of the lagged dependent variable streamlines the model but causes problems of endogeneity, which cannot be solved by traditional methods (for example 2SLS (two-stage least squares), 3SLS (three-stage least squares) or SUR (seemingly unrelated regression)). So, according to these authors, in this case, the best estimation method should be the GMM (generalized method of moments) method in the first differences.

Table 5. Hausman test specification results.

GDPpc—*p*-value = 0.5132	LFP—*p*-value = 0.0147
CO_2—*p*-value = 0.0425	ST—*p*-value = 0.4478
REC—*p*-value = 0.0832	FDI—*p*-value = 0.3547
GCF—*p*-value = 0.0354 R&D—*p*-value = 0.4587	Trade—*p*-value = 0.0254

Source: Authors' calculations. GDPpc—Gross domestic product per capita; CO_2—CO_2 emissions; REC—Renewable energy consumption; GCF—Gross capital formation; R&D—Research and development expenditure; LFP—Labor force participation; ST—School tertiary enrollment; FDI—Foreign direct investment; Trade—International trade.

The estimation using the GMM method in the first differences (as recommended by [42,44]), for the variables that seek to justify the growth rate of GDP per capita, allows the persistence of the dependent variable in time to be considered, in addition to solving potential problems caused by endogeneity.

The GMM model in the first difference takes the following form:

$$\begin{aligned} \text{lnGDPpc}_{\text{it}} = \alpha_i + \beta_1\text{lnGDP}(-1)\text{pc}_{\text{it}} + \beta_2\,\text{lnCO}_{2\text{it}} + \beta_3\,\text{lnREC}_{\text{it}} + \beta_4\,\text{lnGCF}_{\text{it}} + \\ +\beta_5\text{lnR\&D}_{\text{it}} + \beta_6\,\text{lnLFP}_{\text{it}} + \beta_7\,\text{lnST}_{\text{it}} + \beta_8\,\text{lnFDI}_{\text{it}} + \beta_9\,\text{lnTrade}_{\text{it}} + \text{u}_{\text{it}} \end{aligned} \quad (2)$$

Equation (2) regresses the lnGDP per capita as a function of the lnGDP per capita lagged in one year, the ln of CO_2 emissions, the ln of renewable energy consumption, as well as the ln of six control variables: gross capital formation; research and development expenditure; labor force participation; school tertiary enrollment; foreign direct investment; and international trade.

Table 6 reproduces the estimated results through the panel data fixed effects methodology and the GMM methodology in the first differences. The first major conclusion we can draw is that, since the coefficient of the dependent variable lagged in a period is 0.91 (in model 3), it reveals the high persistence of the effect of the previous year's economic growth, that is, only about 9% of the economic growth is adjusted the following year. In the case of model 4, the coefficient of the dependent variable lagged is 0.93; this also reveals the high persistence of the economic growth of the previous year because, in this case, only about 7% of the economic growth is adjusted the following year.

In the fixed-effects model, there is a greater number of variables with statistical significance than in the GMM model, but the GMM model does not present endogeneity; therefore, it does not compromise the reliability of the estimated coefficients or its statistical inference.

Models 1 and 3 consider all variables, but model 2 does not consider CO_2 emissions, and in model 4, the variables that do not present statistical significance in model 3 were removed, as they included renewable energy consumption without considering CO_2 emissions and without statistically insignificant variables.

In model 2, we found that all variables that were statistically significant in model 1 remained so, with the variables gross capital formation, research and development expenditure, labor force participation, and international trade still reinforcing their contribution to economic growth. Concerning model 4, the variables that had statistical significance in model 3 maintained their significance. The previous results found that, in the case of renewable energy consumption, the effects of the persistence of the dependent variable over time are reinforced.

Table 6. Results from the estimations.

	Dependent Variable: lnGDPpc			
	Fixed Effects		GMM First Differences	
	Model 1 Coefficients	**Model 2 Coefficients**	**Model 3 Coefficients**	**Model 4 Coefficients**
Intercept	4.53741 ***	4.98322 ***	6.00215 ***	6.12148 ***
lnGDPpc (−1)			0.91416 ***	0.93148 ***
$lnCO_2$	0.02116 ***		0.01243 *	
lnREC	0.11850 ***	0.09212 **	0.05474 **	0.09751 ****
lnGCF	0.19670 ***	0.21579 ***	0.03409 *	0.03375 *
lnR&D	0.07503 ***	0.09505 ***	0.00413	
lnLFP	0.25339 ***	0.32933 ***	0.05123	
lnST	0.33100 ***	0.32435 *	0.03300 **	0.02784 ***
lnFDI	0.01225 ***	0.00947 *	0.00020	
lnTrade	0.43277 ***	0.44165 ***	0.09313 ***	0.01022 ***
R-Squared	0.97951	0.97818		
F-test (*p*-value)	9.90083×10^{-3}	4.72714×10^{-3}		
Breus–Pagan test (*p*-value)	0	0		
Hausman test (*p*-value)	3.65478×10^{-3}	4.65478×10^{-3}		
Observations	702	702		

Note: ***, ** and * denote statistical significance at the 1%, 5% and 10% level of significance respectively. GDPpc—Gross domestic product per capita; CO_2—CO_2 emissions; REC—Renewable energy consumption; GCF—Gross capital formation; R&D—Research and development expenditure; LFP—Labor force participation; ST—School tertiary enrollment; FDI—Foreign direct investment; Trade—International trade. Source: Authors' estimations.

5. Discussion

As we can see in Table 6, in the two estimations using fixed effects, all variables assume statistical significance for normally considered levels. The two main independent variables of this study (CO_2 emissions from burning fossil fuels and renewable energy consumption in relation to final energy consumption) contribute statistically significantly to the per capita economic growth of the European Union countries, as already verified in other studies [12,23,31,33] (among others). In our case, an important piece of evidence must be highlighted, which is the impact of these two variables on economic growth, with the impact of renewable energy consumption with respect to total energy consumption being higher than the contribution made by CO_2 emissions from burning fossil fuels. Under that condition, ceteris paribus, a 1% increase in the renewable energy consumption–total energy consumption ratio contributes to an increase in GDP per capita of 0.1185%; in the case of CO_2, however, the increase is only 0.021%, that is, an impact of about five times less. This evidence may mean that the ongoing energy transition, which is intended to decarbonize energy consumption and replace it with renewable energy consumption, will contribute positively in net terms to economic growth, despite the loss associated with the decrease in CO_2 emissions.

In Table 6, and model 2 (without the CO_2 variable), all other variables continue to show statistical significance for economic growth in the European Union. Considering endogeneity, model 4 also reveals that removing the non-significant variables R&D, LFP, and FDI, all the others keep their significance and positiveness in estimations.

Still, regarding the two models with endogeneity, the variable that most contributes to economic growth is the degree of the economy's trade openness to the outside (Trade), and in this case, under ceteris paribus condition, it is estimated that an increase of 1% in this variable causes an increase of more than 0.4% of GDP per capita, showing it as a significant variable for the sample of EU 27 countries and the period of analysis. Its significance appears jointly with the representative variables used for human capital and gross capital formation. Even though previous literature highlights the clear role of trade openness on economic growth, in the context of renewable consumption, a well-trained and highly skilled domestic labor force is required for the adoption of new technology through international trade, especially sustainable technology, that is able to provide sustainable economic growth [45]. However, CO_2 emissions also increase GDP per capita, which could be explained by the EU 27's high dependence on fossil fuels as considered in our sample. Another very impactful variable in economic growth (which is verified in the four models) is the tertiary school (ST), which once again reveals the important role that tertiary education plays in preparing students to enter the job market. More educated students increase work productivity, which impacts the profitability of companies and economic growth, in addition to the workers enjoying higher wages. It is also important to mention the positive externalities that occur when these more qualified workers spill over to other workers, triggering a virtuous cycle in companies and nations [46]. Thus, policymakers and governments should regard trade and human capital as clean energy-fostering mechanisms when developing energy demand policies that are environmentally friendly.

In the same sense, the variable labor force participation (LFP) also has a high impact on economic growth, when disregarding endogeneity, along with investment in fixed assets (GCF). In a global environment of intense competitive changes, correct and appropriate investments become economic results in the future, improving the performance of companies and economies. Moreover, a lack of awareness regarding the adversities associated with environmental pollution that is caused by non-educated populations or lack of sufficient human capital may trigger negative environmental consequences [37,39]. Still, as shown by the results in Table 6, all independent variables coefficients are positive, indicating that more efforts are necessary to promote economic growth in a sustainable way. Based on the sample analyzed here, substitution of fossil fuels by renewable energy sources may seem to be the best solution.

Concerning the FDI variable, it is considered to be an important driver in the economic growth of the countries that receive it for several reasons. According to [47], FDI is a fundamental factor in international economic integration, as it allows companies to organize their production across countries and form global value chains that contribute to the creation of a more competitive business environment [36]. Globalization, through participation in international trade and attraction of foreign direct investment, may lead to the expansion of pollution-intensive industries, especially in developing countries, where these nations are at risk of turning into pollution havens [36]. Other authors found opposing results [35], suggesting that FDI plays a key role in economic growth and simultaneously drives environmental sustainability. Our results are consistent with authors who are defending a positive role of FDI over GDP per capita, but the significance of the variable is not kept when endogeneity issues are addressed.

Finally, regarding R&D, the effect on GDP per capita is the smallest of all, but it also has a positive and significant effect. When endogeneity is addressed, the sign is kept but the significance is lost. Grafström et al. [33] mention that countries with deregulated energy markets and with lower energy-import dependence receive less government R&D support. In the EU 27 group, energy markets are becoming more deregulated, and policies are being redirected to decrease fossil fuel energy dependence and increase quotas for renewable energy productions. Still, more efforts in R&D support and the associated clean technologies and gross capital investment are necessary to reach independence in terms of energy production and consumption, and the necessary infrastructures to support renewables are needed to ensure sustainable economic growth [48].

One of the biggest differences between the two types of estimation is that, in the GMM in the first differences, some control variables lose their statistical significance, including R&D, LFP, and FDI. However, it should be noted that in these estimates (model 3) the variable that quantifies CO_2 emissions from burning fossil fuels does not show statistical significance, but renewable energy consumption in the country continues to maintain this significance. In models without endogeneity, the control variables ST, Trade, and GFC continue to maintain statistical significance, although their contribution to the formation of GDP per capita has decreased in relation to models with endogeneity. This is because the persistent effect from the previous year was excluded due to the small adjustment made in the following year.

It can be expected that a low economic growth level, alongside predominant fossil fuel dependency and technological backwardness, is responsible for environmental distress, which should be more visible in developing countries [33,34,36]. In EU 27, we are still noticing economic growth at the expense of more CO_2 emissions, even if renewable energy consumption is demonstrated to improve economic growth. Thus, policymakers should redirect and focus their attention on the promotion of lower energy dependence which we believe to be the highest problem in this group of countries. As pointed out by [1], fossil fuels are a considerable source of carbon emissions and environmental degradation. This result causes us to return the introduction, where the question of policy priorities has been addressed. Considering the type of countries under analysis, the current priority should be in the promotion of renewable sources, reducing EU 27 energy dependency, and ensuring sustainable growth as is necessary for agreements designed to fight climate change and environmental degradation.

If, as pointed out by [17] and by [18], moving towards renewable energy leads to economic development besides economic growth by reducing carbon emissions, our results indicate that the EU 27 group is on the correct track, but is still far from reaching the necessary goals of climate change neutrality, considering the simultaneously found positive impact of CO_2 emissions on economic growth. Globalization and trade foster the flow of eco-friendly technologies and modern innovative methods of production, namely in terms of renewable energy product development, ensuring low carbon emissions. For developing nations, technology stock is already low and globalization can promote technology spillovers, helping them to protect their environmental attributes. Additionally, the usual bad management of natural resources delays development in these countries, thereby decreasing economic growth. However, in the majority of the EU 27, we are dealing with supposedly developed economies, and in face of these results, we can argue that policymakers and governments should promote a more effective and aggressive policy of renewables promotion, adopting technologies that: enable the production and consumption of renewables; continue to promote and support R&D expenses, namely in renewable sources of energy; betting on human capital development (and being open-minded about new technologies and environmental awareness); and promoting gross capital investment and trade. Only then will we be able to observe lower levels of energy dependency in Europe. Additionally, governments and policymakers should create the necessary conditions for a globally deregulated energy market in Europe, which clearly demands the necessary connecting infrastructures and the funds that could be obtained through the European CO_2 emissions licenses market to turn effective the principles of pollutant–payer. For an equilibrium to be reached, and for reasons of fairness, this market should embrace all the economic activity sectors in the economies of the EU 27 group.

6. Conclusions

This study explores the impacts of: renewable energy consumption; CO_2 emissions from burning fossil fuels; investments made in fixed assets; investment in R&D; amount of population providing labor force for the production of goods and services; the level of human capital qualifications; amount of foreign investment in a country; and involvement in a country's international trade, based on the economic growth for the group of EU 27 countries during 1994 and 2019. We tried to address the identified gap in the literature regarding the lack of consensus respecting the effects of these variables on economic growth and the contradictory findings for the different variables. A more complete approach includes six variables simultaneously in the study of the nexus of CO_2 emissions–renewables–growth for an extended period of analysis and considering endogeneity in the empirical applications.

Results highlight the positive persistent and significant effects of CO_2 emissions, renewables energy consumption, gross fixed capital investment, human capital, and trade, on economic growth, which we justify by the still high dependency of the EU 27 group on fossil fuels. Since energy is an important source of economic growth in worldwide economies, sustainable economic growth can only be achieved through prior creation of the conditions necessary to expand the production and consumption of renewables. This can only be achieved through human capital, innovative technologies able to respond to the demand, imposition of the necessary renewable sources, and continued trade openness (and here we include the unique desired electricity market network in Europe). Only then will Europe be able to grow in a sustainable way that ensures the necessary reduction of CO_2 emissions.

Despite the interesting findings, namely, that the impact of renewable energy consumption concerning total energy consumption is higher than the contribution made by CO_2 emissions from burning fossil fuels, this work presents some limitations regarding the impossibility of extending the period of analysis to provide an individual country analysis. Consequently, policies associated with the particular macroeconomic and microeconomic conditions that exist within a particular country are difficult to include as they relate to specific energy or governmental impositions. Still, the evidence provided here may mean that the ongoing energy transition, which is intended to decarbonize energy consumption and replace it with renewable energy consumption, will contribute positively in net terms to economic growth, benefiting from the associated decrease in CO_2 emissions.

Author Contributions: Conceptualization, M.M. and M.C.N.; methodology, M.C.N.; software, M.C.N.; validation, M.M. and M.C.N.; formal analysis, M.M.; investigation, M.C.N.; writing—original draft preparation, M.M. and M.C.N.; writing—review and editing, M.M. and M.C.N.; supervision, M.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data will be made available by the authors upon reasonable request.

Acknowledgments: This work was supported by the Research Unit on Governance, Competitiveness and Public Policies (GOVCOPP), through the Portuguese Foundation for Science and Technology (FCT—Fundação para a Ciência e a Tecnologia), reference UIDB/04058/2020.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Bhuiyan, M.; Zhang, Q.; Khare, V.; Mikhaylov, A.; Pinter, G.; Huang, X. Renewable Energy Consumption and Economic Growth Nexus—A Systematic Literature Review. *Front. Environ. Sci.* **2022**, *10*, 878394. [CrossRef]
2. Apergis, N.; Payne, J.E. Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. *Energy Policy* **2010**, *38*, 656–660. [CrossRef]
3. Xie, P.; Zhu, Z.; Hu, G.; Huang, J. Renewable energy and economic growth hypothesis: Evidence from N-11 countries. *Econ. Res.-Ekonomska Istraživanja* **2022**, 1–21. [CrossRef]
4. Wang, C.; Elfaki, K.E.; Zhao, X.; Shang, Y.; Khan, Z. International trade and consumption-based carbon emissions: Does energy efficiency and financial risk ensure sustainable environment? *Sustain. Dev.* **2022**, *30*, 1451–1461. [CrossRef]
5. Zhao, X.; Ramzan, M.; Sengupta, T.; Deep Sharma, G.; Shahzad, U.; Cui, L. Impacts of bilateral trade on energy affordability and accessibility across Europe: Does economic globalization reduce energy poverty? *Energy Build.* **2022**, *262*, 112023. [CrossRef]
6. Qudrat-Ullah, H.; Nevo, C.M. The impact of renewable energy consumption and environmental sustainability on economic growth in Africa. *Energy Rep.* **2021**, *7*, 3877–3886. [CrossRef]
7. Xu, Y.; Li, S.; Zhou, X.; Shahzad, U.; Zhao, X. How environmental regulations affect the development of green finance: Recent evidence from polluting firms in China. *Renew. Energy* **2022**, *189*, 917–926. [CrossRef]
8. Mohsin, M.; Kamran, H.W.; Nawaz, M.A.; Hussain, M.S.; Dahri, A.S. Assessing the impact of transition from nonrenewable to renewable energy consumption on economic growth-environmental nexus from developing Asian economies. *J. Environ. Manag.* **2021**, *284*, 111999. [CrossRef]
9. Brady, G.L.; Magazzino, C. The relationship among renewable energy, economic growth, labor and capital formation in Italy. *Riv St Sulla Sost* **2018**, *6*, 35–48. [CrossRef]
10. Banday, U.J.; Murugan, S.; Maryam, J. Foreign direct investment, trade openness and economic growth in BRICS countries: Evidences from panel data. *Transnatl. Corp. Rev.* **2021**, *13*, 211–221. [CrossRef]

11. Elfaki, K.E.; Handoyo, R.D.; Ibrahim, K.H. The impact of industrialization, trade openness, financial development, and energy consumption on economic growth in Indonesia. *Economies* **2021**, *9*, 174. [CrossRef]
12. Balsalobre-Lorente, D.; Leitão, N.C. The role of tourism, trade, renewable energy use and carbon dioxide emissions on economic growth: Evidence of tourism-led growth hypothesis in EU-28. *Environ. Sci. Pollut. Res. Int.* **2020**, *27*, 45883–45896. [CrossRef] [PubMed]
13. Inglesi-Lotz, R. The impact of renewable energy consumption to economic growth: A panel data application. *Energy Econ.* **2016**, *53*, 58–63. [CrossRef]
14. Singh, N.; Nyuur, R.; Richmond, B. Renewable Energy Development as a Driver of Economic Growth: Evidence from Multivariate Panel Data Analysis. *Sustainability* **2019**, *11*, 2418. [CrossRef]
15. Chen, C.; Pinar, M.; Stengos, T. Renewable energy consumption and economic growth nexus: Evidence from a threshold model. *Energy Policy* **2020**, *139*, 111295. [CrossRef]
16. Gyimah, J.; Yao, X.; Tachega, M.; Hayford, I.; Opoko-Mensah, E. Renewable energy consumption and economic growth: New evidence from Gana. *Energy* **2022**, *248*, 123559. [CrossRef]
17. Tu, Z.; Feng, C.; Zhao, X. Revisiting energy efficiency and energy related CO_2 emissions: Evidence from RCEP economies. *Econ. Res.-Ekonomska Istraživanja* **2022**, *35*, 1–21. [CrossRef]
18. Gielen, D.; Boshell, F.; Saygin, D.; Bazilian, M.D.; Wagner, N.; Gorini, R. The role of renewable energy in the global energy transformation. *Energy Strategy Rev.* **2019**, *24*, 38–50. [CrossRef]
19. Alsaleh, M.; Abdul-Rahin, A. Bioenergy consumption and economic growth in the EU-28 region: Evidence from a panel cointegration model. *GeoJ* **2021**, *86*, 1245–1260. [CrossRef]
20. Gabr, E.; Mohamed, S. Energy management model to minimize fuel consumption and control harmful gas emissions. *Int. J. Energy Water Res.* **2020**, *4*, 453–463. [CrossRef]
21. Suki, N.M.; Sharif, A.; Afshan, S.; Suki, N.M. Revisiting the Environmental Kuznets Curve in Malaysia: The role of globalization in sustainable environment. *J. Clean. Prod.* **2020**, *264*, 121669. [CrossRef]
22. Wei, J.; Rahim, S.; Wang, S. Role of environmental degradation, institutional quality, and government health expenditures for human health: Evidence from emerging seven countries. *Front. Public Health* **2022**, *10*, 870767. [CrossRef] [PubMed]
23. Jiang, S.; Chishti, M.Z.; Rjoub, H.; Rahim, S. Environmental R&D and trade-adjusted carbon emissions: Evaluating the role of international trade. *Environ. Sci. Pollut. Res.* **2022**, *29*, 63155–63170. [CrossRef]
24. Shahzad, U.; Radulescu, M.; Rahim, S.; Isik, C.; Yousaf, Z.; Ionescu, S.A. Do environment-related policy instruments and technologies facilitate renewable energy generation? Exploring the contextual evidence from developed economies. *Energies* **2021**, *14*, 690. [CrossRef]
25. Chang, C.L.; Fang, M. Renewable energy-led growth hypothesis: New insights from BRICS and N-11 economies. *Renew. Energy* **2022**, *188*, 788–800. [CrossRef]
26. Kasperowicz, R.; Bilan, Y.; Štreimikienė, D. The renewable energy and economic growth nexus in European countries. *Sustain. Dev.* **2020**, *28*, 1086–1093. [CrossRef]
27. Namahoro, J.P.; Nzabanita, J.; Wu, Q. The impact of total and renewable energy consumption on economic growth in lower and middle-and upper-middle-income groups: Evidence from CS-DL and CCEMG analysis. *Energy* **2021**, *237*, 121536. [CrossRef]
28. Okumus, I.; Guzel, A.E.; Destek, M.A. Renewable, non-renewable energy consumption and economic growth nexus in G7: Fresh evidence from CS-ARDL. *Environ. Sci. Pollut. Res. Int.* **2021**, *28*, 56595–56605. [CrossRef]
29. Hao, L.-N.; Umar, M.; Khan, Z.; Ali, W. Green Growth and Low Carbon Emission in G7 Countries: How Critical the Network of Environmental Taxes, Renewable Energy and Human Capital Is? *Sci. Total Environ.* **2021**, *752*, 141853. [CrossRef]
30. Fang, W.; Liu, Z.; Putra, A.R.S. Role of research and development in green economic growth through renewable energy development: Empirical evidence from South Asia. *Renew. Energy* **2022**, *194*, 1142–1152. [CrossRef]
31. Hussain, Z.; Mehmood, B.; Khan, M.K.; Tsimisaraka, R.S. Green Growth, Green Technology, and Environmental Health: Evidence from High-GDP Countries. *Front. Public Health* **2022**, *9*, 816697. [CrossRef] [PubMed]
32. Ahmad, M.; Jiang, P.; Majeed, A.; Umar, M.; Khan, Z.; Muhammad, S. The dynamic impact of natural resources, technological innovations and economic growth on ecological footprint: An advanced panel data estimation. *Res. Policy* **2020**, *69*, 101817. [CrossRef]
33. Grafström, J.; Söderholm, P.; Gawel, E.; Lehmann, P.; Strunz, S. Government support to renewable energy R&D: Drivers and strategic interactions among EU Member States. *Econ. Innov. New Technol.* **2023**, *32*, 1–24. [CrossRef]
34. Topcu, E.; Altinoz, B.; Aslan, A. Global evidence from the link between economic growth, natural resources, energy consumption, and gross capital formation. *Res. Policy* **2020**, *66*, 101622. [CrossRef]
35. Abdouli, M.; Hammami, S. Economic growth, FDI inflows and their impact on the environment: An empirical study for the MENA countries. *Qual. Quant. In.t J. Method* **2017**, *51*, 121–146. [CrossRef]
36. Hao, Y. Effect of Economic Indicators, Renewable Energy Consumption and Human Development on Climate Change: An Empirical Analysis Based on Panel Data of Selected Countries. *Front. Energy Res.* **2022**, *10*, 841497. [CrossRef]
37. Mahmood, N.; Wang, Z.; Hassan, S.T. Renewable energy, economic growth, human capital, and CO_2 emission: An empirical analysis. *Environ. Sci. Pollut. Res.* **2019**, *26*, 20619–20630. [CrossRef]
38. Sarkodie, S.A.; Adams, S.; Owusu, P.A.; Leirvik, T.; Ozturk, I. Mitigating degradation and emissions in China: The role of environmental sustainability, human capital and renewable energy. *Sci. Total Environ.* **2020**, *719*, 137530. [CrossRef]

39. Meyer, A. Heterogeneity in the preferences and pro-environmental behavior of college students: The effects of years on campus, demographics, and external factors. *J. Clean. Prod.* **2016**, *112*, 3451–3463. [CrossRef]
40. Gujarati, D. *Basic Econometrics*, 5th ed.; McGraw Hill Publishing Company: New York, NY, USA, 2009.
41. Wooldridge, J. *Introductory Econometrics: A Modern Approach*; Cengage Learning: Boston, MA, USA, 2013.
42. Arellano, M.; Bond, S. Some tests of specification for panel data: Monte Carlo evidence and application to employment equations. *Rev. Econ. Stud.* **1991**, *58*, 277–297. [CrossRef]
43. Arellano, M.; Bover, O. Another look at the instrumental variable estimation of error- components model. *J. Econom.* **1995**, *68*, 29–51. [CrossRef]
44. Blundell, R.; Bond, S. Initial conditions and moment restrictions in dynamic panel data models. *J. Econom.* **1998**, *87*, 115–143. [CrossRef]
45. Ge, M.; Kannaiah, D.; Li, J.; Khan, N.; Shabbir, M.S.; Bilal, K.; Tabash, M.I. Does foreign private investment affect the clean industrial environment? Nexus among foreign private investment, CO_2 emissions, energy consumption, trade openness, and sustainable economic growth. *Environ. Sci. Pollut. Res.* **2022**, *29*, 26182–26189. [CrossRef] [PubMed]
46. Nogueira, M.; Afonso, O. Engines of the Skill Premium in the Portuguese Economy. *CESifo Econ. Stud.* **2019**, *65*, 318–341. [CrossRef]
47. OECD. *OECD Factbook 2015–2016: Economic, Environmental and Social Statistics*; OECD Publishing: Paris, France, 2016.
48. Chen, H.; Shi, Y.; Zhao, X. Investment in renewable energy resources, sustainable financial inclusion and energy efficiency: A case of US economy. *Res. Policy* **2022**, *77*, 102680. [CrossRef]