energies

Article

The Impact of Economic Factors on the Sustainable Development of Energy Enterprises: The Case of Bulgaria, Czechia, Estonia and Poland

Anna Misztal [1,*], Magdalena Kowalska [1] and Anita Fajczak-Kowalska [2]

[1] Faculty of Economics and Sociology, University of Lodz, 90-214 Lodz, Poland
[2] Institute of Information Technology, Lodz University of Technology, 90-924 Lodz, Poland
* Correspondence: anna.misztal@uni.lodz.pl

Abstract: The sustainable development of enterprises is based on three pillars: economic, social, and environmental. Sustainable development aims to limit climate change and its negative impact on the natural environment. The main aim of this paper is to assess the impact of selected energy economy factors (government expenditure, environmental taxes, outlays on renewable energy sources, prices of futures contracts for CO_2 emissions, outlays on R&D, and the EU Emissions Trading System (ETS_{EU})) on the sustainable development of the energy sectors in Bulgaria, Czechia, Estonia, and Poland, from 2008 to 2022. We use the correlation coefficients, the Ordinary Least Squares (OLS), Vector Autoregressive (VAR) Models, and the simultaneous equation. The research results indicate a variation in the direction and strength of the influence of individual economic factors in the studied countries ($p < 0.05$). The results can support operational and strategic decisions sustaining the sustainable development of enterprises in the analyzed countries. The results indicate the need to reform selected economic factors, with an emphasis on the increased importance of environmental taxes and the reform of the EU ETS, which is a key tool for reducing greenhouse gas emissions cost-effectively.

Keywords: sustainable development; climate change; economic factors; energy sector

check for updates

Citation: Misztal, A.; Kowalska, M.; Fajczak-Kowalska, A. The Impact of Economic Factors on the Sustainable Development of Energy Enterprises: The Case of Bulgaria, Czechia, Estonia and Poland. *Energies* **2022**, *15*, 6842. https://doi.org/10.3390/en15186842

Academic Editors: Carla Oliveira Henriques and Elisabete Neves

Received: 28 August 2022
Accepted: 13 September 2022
Published: 19 September 2022

1. Introduction

The energy sector's sustainable development (SD) is essential to combat climate change, and it incorporates three aspects (economic: E, social: S, and environmental: Env) which should simultaneously interpenetrate and complement each other. SD depends on several internal and external factors [1–4], including the appropriate financial security of enterprises [5,6], an ecological awareness of managers and customers [7], the R&D and innovation [8,9], and macroeconomic stabilization [1,10].

Sustainable energy policies are supported by properly selected and adapted economic instruments (direct and indirect). The experiences of developed countries show that energy policies are largely based on extensive and effective systems of direct regulation instruments (administrative and legal instruments), supplemented with indirect regulation instruments (economic instruments) [11–14].

Key research on the impact of regulations and instruments on the development of the energy sector indicates that the need for implementing regulatory reforms has contributed to productivity growth in developed countries' steam power generation sector [15]. Moreover, the researchers proved that the operations rate, the share of the energy-intensive industries, and social capital significantly impact energy productivity [16]. Some studies suggest that market and environmental regulations do not have unidirectional impacts on total energy productivity [17].

Our study aims to supplement the literature on the subject with the impact of selected economic factors (government expenditure: G_E, environmental taxes: Tax_{EN}, shares of primary energy from renewable sources: R_S, prices of futures contracts for CO2 emissions: P_{CO2}, outlays on R&D: RD, and the EU Emissions Trading System: ETS_{EU}) on the SD of the energy sector in Bulgaria, the Czechia, Estonia, and Poland, from 2008 to 2022. We analyze the countries from Central and Eastern Europe with the highest air pollutants and greenhouse gas levels, based on carbon dioxide emissions in 2020 (air emission accounts are determined by NACE Rev. 2 activity. Electricity, gas, steam, and air conditioning supply: D (kilograms per capita)).

The novelty of our research is in the proprietary evolution of SD indicators and their pillars, based on selected analytical indicators previously used to estimate levels of development in other sectors of the economy. The added value of the paper is evident in its endeavor to create models that show the impact of selected economic instruments on the sustainable development of the energy sector.

We use the correlation coefficients (Pearson's r, Spearman's rho, gamma, and Kendall rank correlation coefficients), the Ordinary Least Squares (OLS), Vector Autoregressive (VAR) Models, and the simultaneous equations. These methods are appropriate for estimating the unknown parameters in a linear regression model (our data are annual and the series is time-based). Our models meet the estimation conditions, including no collinearity, homoscedasticity, normal distribution of variables, and no autocorrelation.

Although the presented models have limitations associated with the selection of analytical indicators, research methods are designed to support managers of enterprises in making operational and strategic decisions. They can also support the authorities of the European Union in making findings regarding the directions of reforms of energy economy factors.

The study includes an introduction, theoretical background, research methodology, results, discussion, and conclusion. The review of scientific publications was based on the Scopus and Web of Science lists. The data for the analysis come from Eurostat and Reuters databases. For the calculations, we used Statistica and Gretl software.

2. Theoretical Background

Sustainable development is a holistic approach that responds to climate change and environmental and social threats [1]. Its essence is to ensure stable and equal conditions for the present and future generations' development [18,19]. Enterprise SD is an integrated and balanced development in social, environmental, and economic spheres [1,20–22]. It can also be defined as development that meets the needs of the company's current and future stakeholders [23–25]. SD requires the implementation of ecological innovations, scientific and technological development, the design of new products and services, and the entering of new markets [26].

The sustainable development of the energy sector is a comprehensive and widespread issue in the literature. Researchers focus on defining and measuring sustainable energy development [27], energy security [28], the diversification of energy sources [29], energy efficiency [30], the impact of macroeconomic factors on the sector's development [1,20,31], energy economic instruments [13,15,16], renewable energy sources [14,32], and innovations implemented in the energy sector [9,26].

Energy SD can be understood as "a guarantee that future generations will have energy resources that will enable them to achieve the same level of well-being as the one that the present generation has [32]". It requires the following principles: the diversification of energy resources and energy generation sources, the improvement of energy efficiency, the ensuring of energy affordability, the provision of consumers with free access to energy sources at an affordable price, and the production of green energy [33–37].

Energy SD depends on various factors, both external (macroeconomic conditions, economic situation, regulations in the field of environmental protection, innovation, access to external sources of financing) and internal (related to the financial and property situation of companies, approaches to environmental protection, the scale and effects of activities, the level of innovation of the enterprise) [1,24,38].

Economic energy factors have a direct and indirect impact on the current and future activities of enterprises [39–41]. Among them, we can distinguish government expenditure, environmental taxes, shares of primary energy from renewable sources, prices of futures contracts for CO2 emissions, outlays on R&D, and the EU Emissions Trading System. Their primary role is to support investments in nature protection and implement environmentally friendly solutions and eco-innovations [42–44].

The previous research results indicate that the impact of the economic instruments on the SD of energy is not unambiguous, and that the strength and direction are varied [45,46]. Researchers indicate that the instruments may have different effects in developed and developing economies, depending on the energy policy, resources available, and the level of renewable energy development [15–17,47,48]. The energy policy of states plays a key role here because it "will determine whether investment and consumption decisions are steered towards low-carbon options [49]".

Some research shows that market and environmental regulations do not have unidirectional impacts on energy productivity. The research based on the 19 European Union countries indicates that the energy efficiency index is negatively affected by sectorial regulation that positively affects the shift of the technological frontier [50]. Research regarding the Japanese market shows that regulatory reforms have contributed to productivity growth in the steam power generation sector [15]. The effectiveness of institutional and economic factors may differ, and instruments should be designed to be adequate to the conditions and possibilities of any country. In countries where conditions are profitable for wind energy development, supporting those instruments that prefer it is necessary [51].

The research carried out in the sustainable energy sector indicates that positive changes are taking place, and SD has an upward trend [52,53]. Moreover, it is emphasized that investing in renewable energy sources and moving away from fossil fuels is the key to stabilizing development [54,55]. In addition, researchers emphasize the importance of changes in legal regulations in the energy field and the implementation of solutions such as emission allowances, which will affect structural changes in the energy sector. It is also emphasized that macroeconomic conditions and fiscal policy may be of key importance for the SD of the energy sector [44,56].

3. Methodology of the Research

The main aim of the research is to assess the impact of G_E, Tax_{EN}, R_S, P_{CO2}, RD, and ETS_{EU} on SD in Bulgaria, Czechia, Estonia, and Poland from 2008 to 2022 (countries with the highest air emissions accounts are determined by NACE Rev. 2 activity in the energy sector. Bulgaria: 13,274.27; Czechia: 8740.75; Estonia: 7456.08; Poland: 8930.11 g per euro) [56]. These economic factors, according to many researchers, are crucial for decreasing the emissions of harmful substances into the environment [12,13,38,45,46]. The raw data for the SD, E, S, and Env come from section D of the NACE Rev. 2 classification.

The direction of the impact of the studied variables has been the subject of many scientific studies [15–17]. Their results are ambiguous and different in developed and developing countries, depending on the macroeconomic and energy policy applied, natural resources available, approach to sustainable energy sources, and adopted strategic goals [13,34,37,52,55]. Our analysis aims to supplement the literature on the subject of the impact of economic factors on SD and its pillars in the developing countries of the EU [1,20]. In this context, we formulated the following **central research hypothesis (H1):**

> *The impact of energy economy factors on the sustainable development of energy sector enterprises is diversified in terms of the strength and direction of impact in the studied countries; moreover, these factors should be used comprehensively, creating a coherent and effective system of supporting factors of the energy transformation.*

This research approach results from considering the argument that there are differences in these countries' energy systems and that sustainable development is a holistic concept and requires a comprehensive approach. We also think the various economic factors functioning as a comprehensive sustainable development system seem correct [30,37,50,55].

We also formulated the following supporting sub-hypotheses:

— **1 Sub-hypothesis (H1):** The economic development of the energy sector shows higher dynamics compared to the social and environmental development in the analyzed countries. This conviction is due to the assumption that the energy sector development in the countries undergoing a relatively recent economic transformation is lagging behind and that the main goal is still to achieve good economic results [2,9,13,29,37,38];

— **2 Sub-hypothesis (H2):** The sustainable development of the energy sector is progressive, and what is more, the results obtained in previous periods are a prerequisite for sustainable development on an ongoing basis. This approach is based on the assumption that investments in the energy sector translate into a later reduction of the negative impact of economic activity on the natural environment [15,46];

— **3 Sub-hypothesis (H3):** The impact of individual energy economy factors on the development pillars (economic, social and environmental) differs in the analyzed countries. This approach is because these factors, by definition, should primarily affect the protection of the environment. Here, it may translate into a reduction in economic and, thus, social development [14,21].

The research includes the following steps:

1. The creation of indicators of SD and its pillars (E, S, Env):
    - Collecting analytical indicators and dividing them into stimulants and destimulants (x_{ij})
        - Economic indicator:
            - Stimulants: enterprises (number), turnover or gross premiums written (EUR 1 million),→production value (mil euro),→value added at factor cost (EUR 1 million), gross operating surplus (EUR 1 million), total purchases of goods and services (EUR 1 million), gross investment in tangible goods (EUR 1 million),→investment rate (%);
            - Destimulants: cost level index from total activity (%);
        - Social indicator:
            - Stimulants: wages and salaries (EUR 1 million), social security costs (EUR 1 million), employees: number, apparent labour productivity, gross value added per employee (EUR 1000), investment per person employed (EUR 1000), employer's social charges as a percentage of personnel costs: percentage (%), expenditure on training and courses;
            - Destimulants: personnel costs (EUR 1 million), share of personnel costs in production (%), accidents at work;
        - Environmental indicator:
            - Destimulants: carbon dioxide, methane nitrous oxide, hydrofluorocarbones (CO_2 equivalent), sulphur oxides (SO_2 equivalent), carbon monoxide, ammonia;
    - Then, we transform the explanatory variables into integrated, using the following formulas [24]:
        - For the stimulants:

$$F_{ij} = \frac{x_{ij}}{\max_i \{x_{ij}\}},\ F_{ij} \in [0;1] \tag{1}$$

        - For the destimulants:

$$F_{ij} = \frac{\min_i x\{x_{ij}\}}{x_{ij}},\ F_{ij} \in [0;1] \tag{2}$$

where: F_{ij} stands for the normalized value of the j-th variable in the i-th year; x_{ij} is the diagnostic variable in i-year.

- We use the following formula to create the SD:

$$SD_{\mathrm{i}} = \frac{\sum_{j=1}^{n} F_{ij}}{n}, \ (\mathrm{i} = 1, 2, \ldots, \mathrm{n}) \tag{3}$$

where: SD*i* indicates integrated variable in *i*-year.

2. We check the level of dependence between the analyzed variables (SD and G_E, Tax_{EN}, R_S, P_{CO2}, RD, ETS_{EU}) using the Pearson's r, Spearman's rho, gamma, and Kendall rank correlation coefficients. We adopt the ranges of correlation strength that were suggested by Evans: $|rxy| = 0$—no correlation; $0 < |rxy| \leq 0.19$—very weak; $0.20 \leq |rxy| \leq 0.39$—weak; $0.40 \leq |rxy| \leq 0.59$—moderate; $0.60 \leq |rxy| \leq 0.79$—strong; $0.80 \leq |rxy| \leq 1.00$—very strong;
3. We create three types of models allowing for the assessment of relationships between variables (dependent variables: SD):
   - Model 1 (the OLS estimation: we used the most common method of fitting a linear model to data, for example, in correlation or regression analysis [56]. It consists of adjusting a straight line that will lie as close as possible to all the results, so that the sum of the distances of all points from the line is minimal), based on the structural equation:

$$\begin{gathered} SD_{\,i} = \hat{\beta}_0 + \hat{\beta}_1 \cdot G_{E\,i} + \hat{\beta}_2 \cdot G_{E\,i-1} + \hat{\beta}_3 \cdot Tax_{EN\,i} + \hat{\beta}_4 \cdot Tax_{EN\,i-1} + \hat{\beta}_5 \cdot R_{S\,i} + \hat{\beta}_6 \cdot R_{S\,i-1} + \hat{\beta}_7 \cdot P_{CO2\,i} + \\ \hat{\beta}_8 \cdot P_{CO2\,i-1} + \hat{\beta}_9 \cdot RD_{\,i} + \hat{\beta}_{10} \cdot RD_{\,i-1} + \hat{\beta}_{11} \cdot ETS_{EU\,i} + \hat{\beta}_{12} \cdot ETS_{EU\,i-1} + \hat{e}_i = \widehat{SD}_i + \hat{e}_i \end{gathered} \tag{4}$$

The residual for each observation is as follows:

$$\hat{e}_i = SD_{\,\mathrm{i}} - \widehat{SD}_i \tag{5}$$

where β_0 is the intercept, $\beta_{1,} \ldots, \beta_{12}$ is the slope; ε_i denotes the *i*-th residual; *i* is an observation index.

We checked the assumption of the method, including unit root tests (KPSS tests), homoscedasticity (the White test), autocorrelation (the Durbin–Watson and Breusch–Godfrey tests), normality (the Doornik–Hansen test), and collinearity (Variance Inflation Factor).

- Model 2 (the Structural Vector Autoregression: VAR, we check the stationarity with the KPSS tests, and we check the optimal lag length using AIC = Akaike criterion, BIC = Schwarz Bayesian criterion and HQC = Hannan–Quinn criterion) [56]:

$$B_{\,0} \cdot SD_{\,i} = c_0 + B_1 \cdot SD_{\mathrm{i}-1} + \cdots + B_p \cdot SD_{\mathrm{i}-\mathrm{p}} + \varepsilon_i \tag{6}$$

where c_0 is a k × 1 vector of constants, *Bi* is a k × k matrix (for every *i* = 0, ... , *p*) and ε_i is a k × 1 vector of error terms. The main diagonal terms of the B_0 matrix (the coefficients on the ith variable in the ith equation) are scaled to 1;

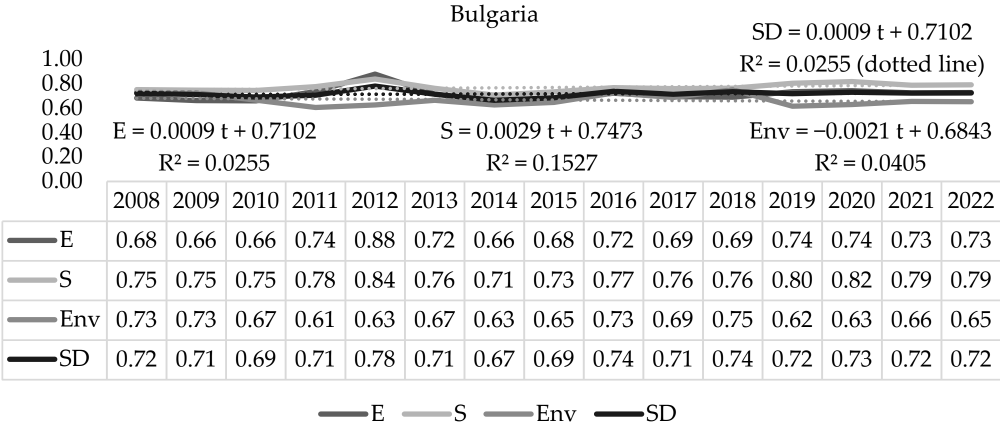
- Model 3 (the OLS estimation), the simultaneous equation is as follows:

$$\begin{cases} \mathrm{E} = \hat{\beta}_0 + \hat{\beta}_1 \cdot G_{E\,i} + \hat{\beta}_2 \cdot Tax_{EN\,i} + \hat{\beta}_3 \cdot R_{S\,i} + \hat{\beta}_4 \cdot P_{CO2\,i} + \\ \quad \hat{\beta}_5 \cdot RD_{\,i} + \hat{\beta}_6 \cdot ETS_{EU\,i} + + \hat{\beta}_7 \cdot S_{\,i} + \hat{\beta}_8 \cdot Env_{\,i} + \hat{e}_i \\ \mathrm{S} = \hat{\beta}_0 + \hat{\beta}_1 \cdot G_{E\,i} + \hat{\beta}_2 \cdot Tax_{EN\,i} + \hat{\beta}_3 \cdot R_{S\,i} + \hat{\beta}_4 \cdot P_{CO2\,i} \\ \quad + \hat{\beta}_5 \cdot RD_{\,i} + \hat{\beta}_6 \cdot ETS_{EU\,i} + \hat{\beta}_7 \cdot E_{\,i} + \hat{\beta}_8 \cdot Env_{\,i} + \hat{e}_i \\ \mathrm{Env} = \hat{\beta}_0 + \hat{\beta}_1 \cdot G_{E\,i} + \hat{\beta}_2 \cdot Tax_{EN\,i} + \hat{\beta}_3 \cdot R_{S\,i} + \hat{\beta}_4 \cdot P_{CO2\,i} \\ \quad + \hat{\beta}_5 \cdot RD_{\,i} + \hat{\beta}_6 \cdot ETS_{EU\,i} + \hat{\beta}_7 \cdot E_{\,i} + \hat{\beta}_8 \cdot Env_{\,i} + \hat{e}_i \end{cases} \tag{7}$$

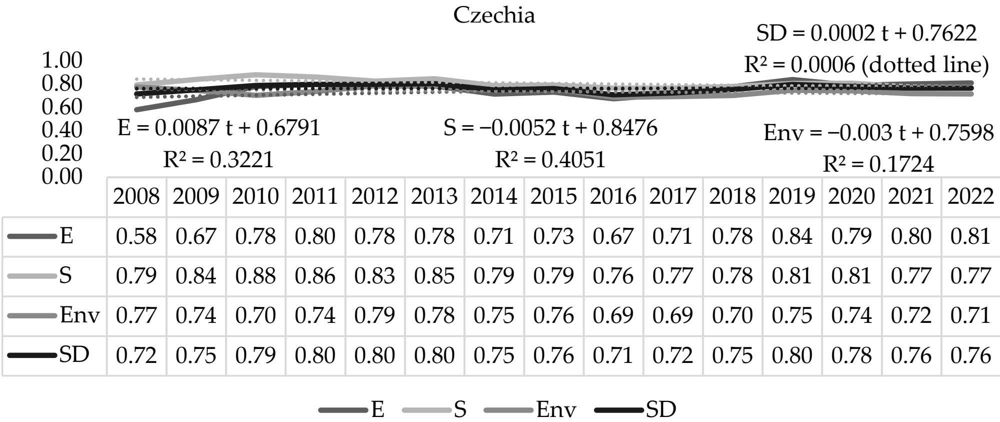
As in the case of model 1, we checked all the conditions of the applicability of the estimation of simultaneous equations using the OLS method.

4. Research Results

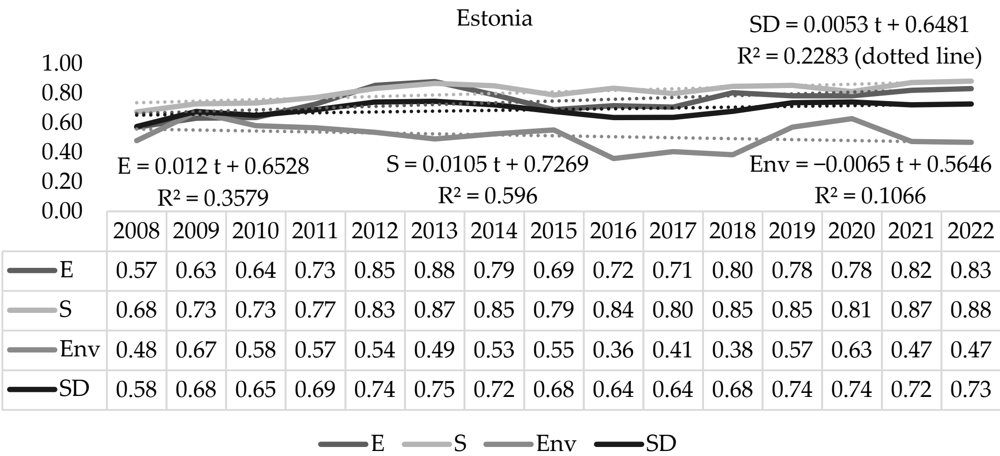
Figure 1 presents the indicators of sustainable development of energy sector enterprises and its three pillars (indicators of the economic, social, and environmental development of energy sector enterprises) in Bulgaria, Czechia, Estonia, and Poland from 2008 to 2022.



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
E	0.68	0.66	0.66	0.74	0.88	0.72	0.66	0.68	0.72	0.69	0.69	0.74	0.74	0.73	0.73
S	0.75	0.75	0.75	0.78	0.84	0.76	0.71	0.73	0.77	0.76	0.76	0.80	0.82	0.79	0.79
Env	0.73	0.73	0.67	0.61	0.63	0.67	0.63	0.65	0.73	0.69	0.75	0.62	0.63	0.66	0.65
SD	0.72	0.71	0.69	0.71	0.78	0.71	0.67	0.69	0.74	0.71	0.74	0.72	0.73	0.72	0.72

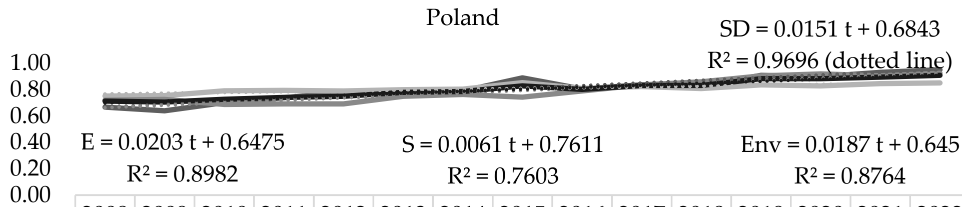


	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
E	0.58	0.67	0.78	0.80	0.78	0.78	0.71	0.73	0.67	0.71	0.78	0.84	0.79	0.80	0.81
S	0.79	0.84	0.88	0.86	0.83	0.85	0.79	0.79	0.76	0.77	0.78	0.81	0.81	0.77	0.77
Env	0.77	0.74	0.70	0.74	0.79	0.78	0.75	0.76	0.69	0.69	0.70	0.75	0.74	0.72	0.71
SD	0.72	0.75	0.79	0.80	0.80	0.80	0.75	0.76	0.71	0.72	0.75	0.80	0.78	0.76	0.76



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
E	0.57	0.63	0.64	0.73	0.85	0.88	0.79	0.69	0.72	0.71	0.80	0.78	0.78	0.82	0.83
S	0.68	0.73	0.73	0.77	0.83	0.87	0.85	0.79	0.84	0.80	0.85	0.85	0.81	0.87	0.88
Env	0.48	0.67	0.58	0.57	0.54	0.49	0.53	0.55	0.36	0.41	0.38	0.57	0.63	0.47	0.47
SD	0.58	0.68	0.65	0.69	0.74	0.75	0.72	0.68	0.64	0.64	0.68	0.74	0.74	0.72	0.73

Figure 1. *Cont.*



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
E	0.67	0.64	0.70	0.74	0.78	0.78	0.79	0.89	0.81	0.84	0.83	0.91	0.90	0.93	0.95
S	0.75	0.75	0.79	0.79	0.79	0.80	0.80	0.85	0.81	0.82	0.81	0.84	0.83	0.85	0.85
Env	0.72	0.73	0.69	0.69	0.69	0.75	0.76	0.74	0.79	0.84	0.86	0.90	0.92	0.91	0.93
SD	0.71	0.71	0.73	0.74	0.75	0.78	0.79	0.83	0.80	0.83	0.83	0.88	0.88	0.89	0.91

E S Env SD

Figure 1. Sustainable development of energy sector enterprises and its pillars in the analyzed countries from 2008 to 2022 (dotted line is SD trend line). Source: own elaboration.

The sustainable development index has a growing trend, while the ecological development indicator in Bulgaria, Estonia, and Czechia is decreasing, which means that economic development is still the foundation in the analyzed countries.

Figure 2 shows selected energy economy factors in Bulgaria, Czechia, Estonia, and Poland from 2008 to 2022.

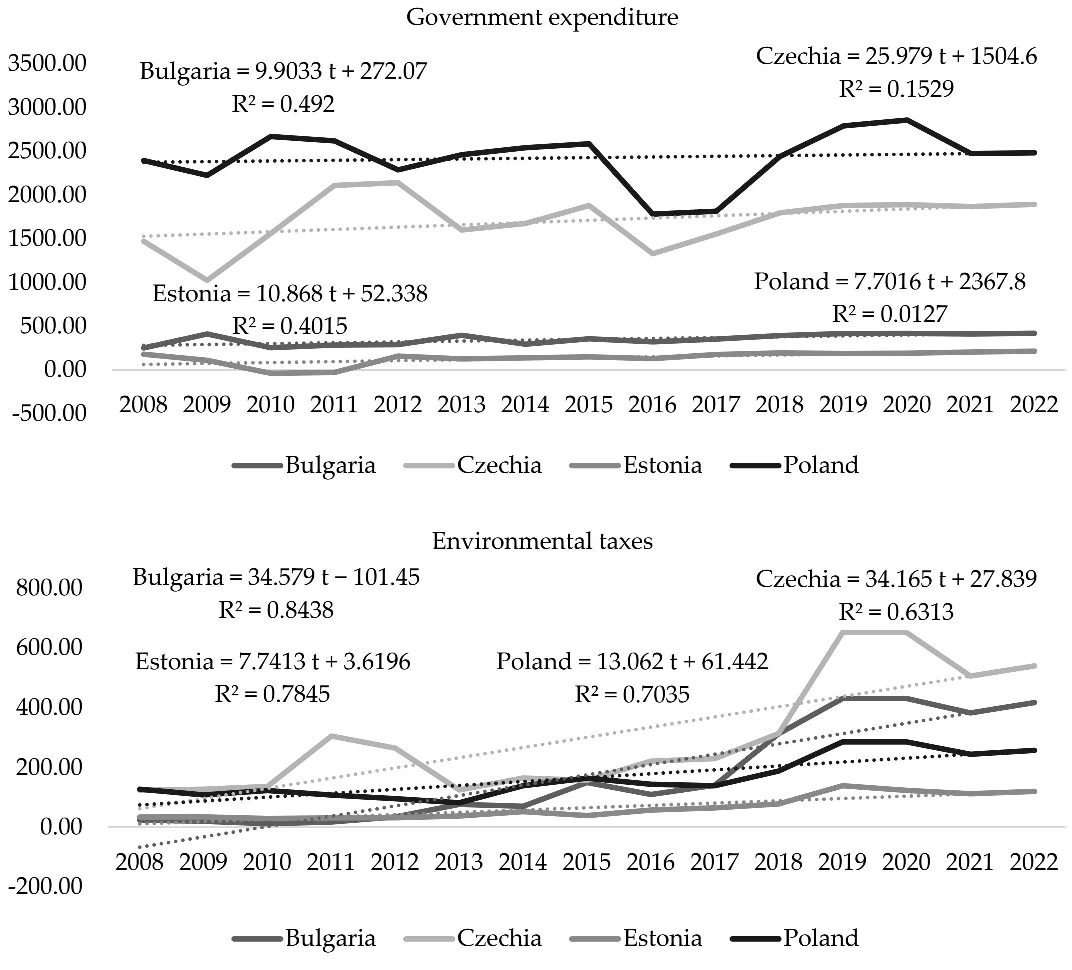


Figure 2. *Cont*.

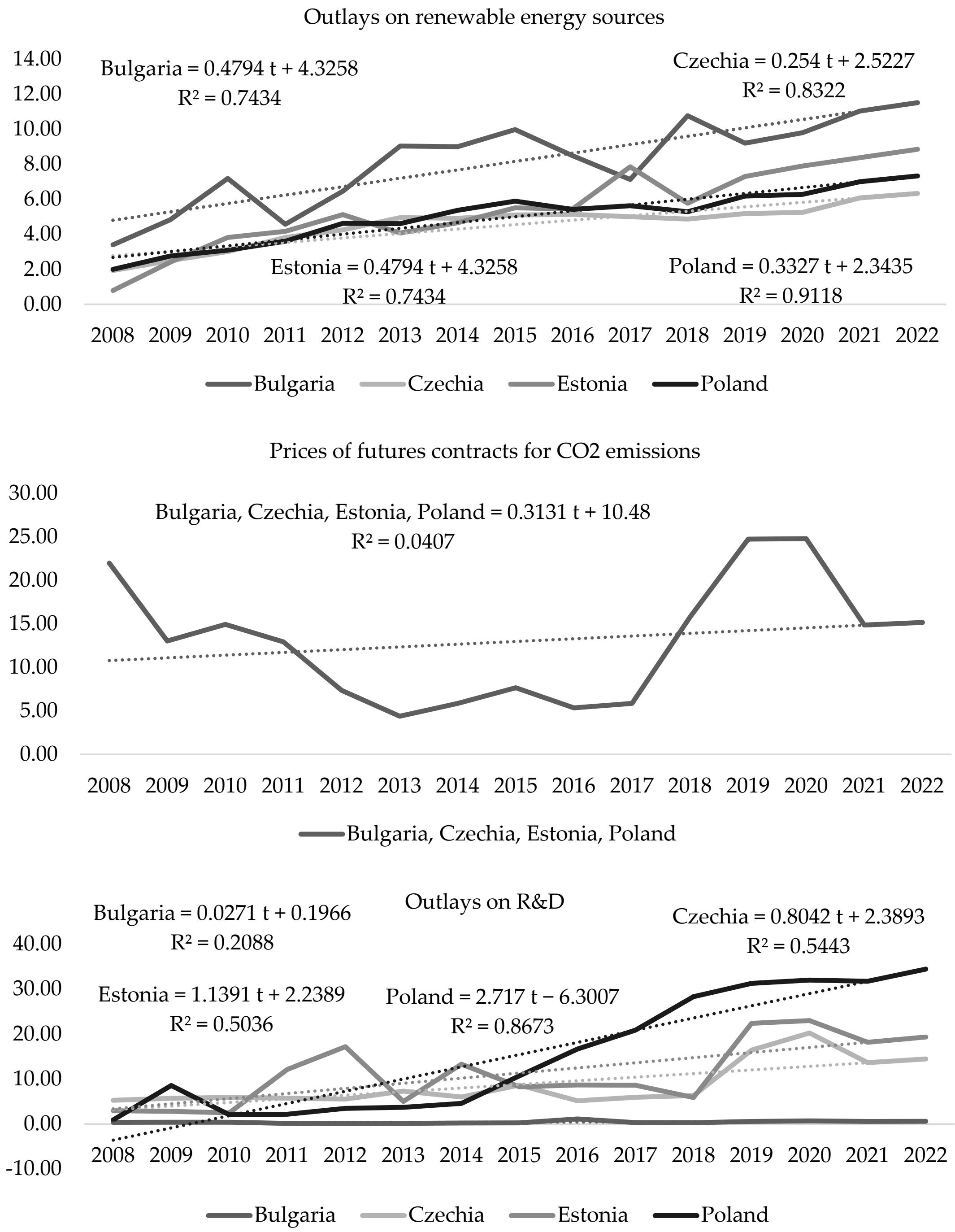


Figure 2. *Cont.*

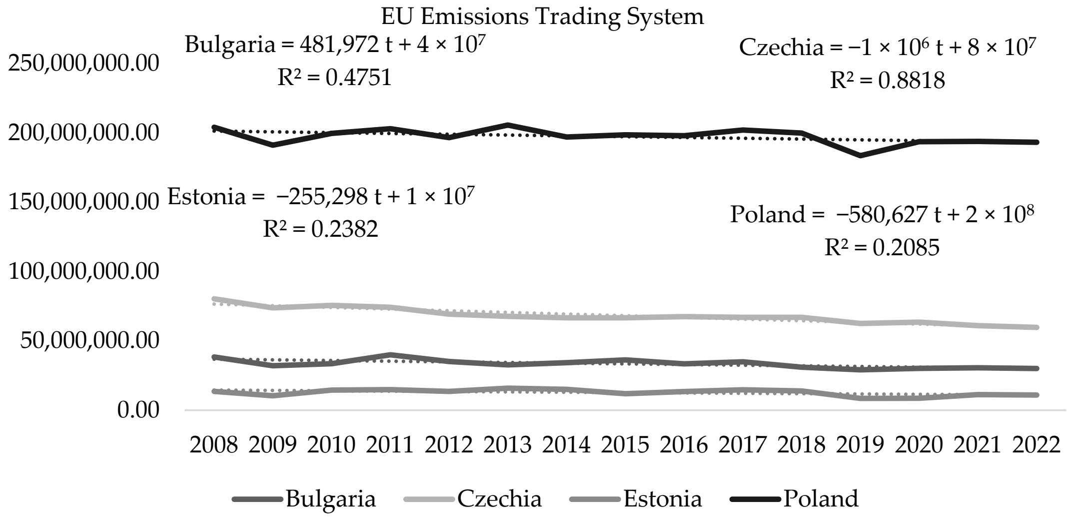


Figure 2. Selected energy economy factors in the analyzed countries from 2008 to 2022 (dotted line is a trend line of the indicators: trend line). Source: own elaboration.

In all countries, the indicators of government expenditure, environmental taxes, outlays on renewable energy sources, the prices of futures contracts for CO_2 emissions, and outlays on R&D display a growing trend, while the indicators of the EU Emissions Trading System is decreasing, which should be assessed positively.

Table 1 presents descriptive statistics of the sustainable development of the energy sector (and its pillars) and selected energy economy factors in Bulgaria, Czechia, Estonia, and Poland from 2008 to 2022.

Table 1. Descriptive statistics of sustainable development of energy sector (and its pillars) and selected energy economy factors in the analyzed countries from 2008 to 2022.

Country	Descriptive Statistics					
	Indicator	**Mean**	**Median**	**Standard Deviation**	**Max**	**Min**
Bulgaria	E	0.71	0.72	0.05	0.88	0.66
	S	0.77	0.76	0.03	0.84	0.71
	Env	0.67	0.66	0.04	0.75	0.61
	SD	0.72	0.72	0.03	0.78	0.67
	G_E	351.30	356.10	61.00	420.62	252.10
	Tax_{EN}	175.18	109.46	162.64	431.00	11.91
	R_S	8.16	9.00	2.40	11.52	3.40
	P_{CO2}	12.98	13.04	6.70	24.81	4.39
	RD	0.41	0.38	0.26	1.12	0.14
	ETS_{EU}	33,432,604.34	33,410,834.00	3,021,138.14	39,997,538.00	29,194,151.00
Czechia	E	0.75	0.78	0.07	0.84	0.58
	S	0.81	0.79	0.04	0.88	0.76
	Env	0.74	0.74	0.03	0.79	0.69
	SD	0.76	0.76	0.03	0.80	0.71
	G_E	1712.39	1796.40	287.00	2143.70	1024.90
	Tax_{EN}	301.16	229.26	185.77	652.00	124.07
	R_S	4.55	4.95	1.20	6.33	1.93
	P_{CO2}	13.00	13.04	6.72	24.98	4.39
	RD	8.82	5.99	4.71	20.25	5.19
	ETS_{EU}	68,167,220.35	66,975,758.00	5,525,183.71	80,399,099.00	59,761,003.04

Table 1. *Cont.*

Country	Descriptive Statistics					
	Indicator	Mean	Median	Standard Deviation	Max	Min
Estonia	E	0.75	0.78	0.09	0.88	0.57
	S	0.81	0.83	0.06	0.88	0.68
	Env	0.51	0.53	0.09	0.67	0.36
	SD	0.69	0.69	0.05	0.75	0.58
	G_E	139.28	158.30	74.10	215.36	−38.10
	Tax_{EN}	65.55	52.17	37.76	139.18	29.36
	R_S	5.47	5.44	2.21	8.85	0.79
	P_{CO2}	13.00	13.04	6.72	24.98	4.39
	RD	11.35	8.67	6.94	23.00	2.51
	ETS_{EU}	12,715,082.07	13,540,891.00	2,259,813.50	15,921,498.00	8,486,473.00
Poland	E	0.81	0.81	0.09	0.95	0.64
	S	0.81	0.81	0.03	0.85	0.75
	Env	0.79	0.76	0.09	0.93	0.69
	SD	0.80	0.80	0.07	0.91	0.71
	G_E	2429.38	2475.59	295.51	2859.10	1783.30
	Tax_{EN}	165.94	138.94	67.28	286.00	81.81
	R_S	5.01	5.37	1.51	7.33	2.00
	P_{CO2}	13.11	13.04	6.86	25.96	4.39
	RD	15.44	10.70	12.60	34.45	0.94
	ETS_{EU}	197,405,309.71	198,051,726.00	5,493,389.68	205,735,395.00	183,690,533.00

Source: own elaboration.

Taking into account the pillars of the indicators of the sustainable development of energy sector enterprises, in the analyzed countries, the highest average level was recorded for the social development of energy sector enterprises, while the lowest was for the environmental development of energy sector enterprises. The highest average level of the indicator of the sustainable development of energy sector enterprises and its pillars in the analyzed period was recorded in Poland. The lowest level of the indicator of the environmental and sustainable development of energy sector enterprises was recorded in Estonia, and the indicator of economic and social development of energy sector enterprises was recorded in Bulgaria.

The highest average level of the selected energy economy factors was recorded in Poland (without the indicator of environmental taxes, Czechia, and the indicator outlays on renewable energy sources, Bulgaria). The lowest average level of the selected energy economy factors was recorded in Bulgaria (without the indicator of environmental taxes and the indicator of EU Emissions Trading System, Estonia, and the indicator outlays on renewable energy sources, Czechia).

Table 2 shows the Pearson's r, Spearman's rho, gamma, and Kendall rank correlation coefficients. The correlation coefficients were determined between the indicators of the sustainable development of energy sector enterprises and the indicators of selected energy economy factors: government expenditure, environmental taxes, outlays on renewable energy sources, the prices of futures contracts for CO2 emissions, outlays on R&D, and the EU Emissions Trading System in Bulgaria, Czechia, Estonia, and Poland from 2008 to 2022.

Table 2. Correlation coefficients between sustainable development of energy sector enterprises and selected energy economy factors in the analyzed countries from 2008 to 2022, $p < 0.05$ (n = 15).

Country	Correlation	Pearson's r	Spearman's Rho	Gamma	Kendall Rank
Bulgaria	SD/G_E	0.1320	0.2607	0.1810	0.1810
	SD/Tax_{EN}	0.1846	0.4143	0.2952	0.2952
	SD/R_S	−0.0340	0.2107	0.1429	0.1429
	SD/P_{CO2}	0.1168	0.2071	0.1619	0.1619
	SD/RD	0.2149	0.3679	0.3143	0.3143
	SD/ETS_{EU}	−0.1836	−0.3679	−0.2190	−0.2190
Czechia	SD/G_E	0.5927	0.6571	0.5429	0.5429
	SD/Tax_{EN}	0.3084	0.2643	0.1810	0.1810
	SD/R_S	0.1336	0.0714	0.0667	0.0667
	SD/P_{CO2}	0.1491	0.0786	0.0857	0.0857
	SD/RD	0.3270	0.3679	0.3333	0.3333
	SD/ETS_{EU}	−0.1673	−0.0286	−0.1238	−0.1238
Estonia	SD/G_E	0.2078	0.2643	0.1619	0.1619
	SD/Tax_{EN}	0.4529	0.3357	0.2952	0.2952
	SD/R_S	0.5148	0.3429	0.2571	0.2571
	SD/P_{CO2}	0.0039	0.1036	0.1238	0.1238
	SD/RD	0.6860	0.5964	0.4857	0.4857
	SD/ETS_{EU}	−0.3152	−0.1214	−0.1048	−0.1048
Poland	SD/G_E	0.1892	0.2536	0.1619	0.1619
	SD/Tax_{EN}	0.8739	0.8464	0.6381	0.6381
	SD/R_S	0.9554	0.9536	0.8667	0.8667
	SD/P_{CO2}	0.2780	0.3250	0.1619	0.1619
	SD/RD	0.9141	0.9071	0.8095	0.8095
	SD/ETS_{EU}	−0.5019	−0.4500	−0.3143	−0.3143

Source: own elaboration.

The correlation coefficients have different levels of strength and directions of impact. The highest level of the correlation coefficient was recorded in Poland, a correlation between the indicator of the sustainable development of energy sector enterprises and the indicator of outlays on renewable energy sources. The lowest level of the correlation coefficient was recorded in Estonia, a correlation between the indicator of the sustainable development of energy sector enterprises and the indicator prices of futures contracts for CO2 emissions.

Table 3 presents the results of the OLS estimation in Bulgaria, Czechia, Estonia, and Poland from 2008 to 2022.

Table 3. Results of OLS regressions in the analyzed countries from 2008 to 2022 ($p < 0.05$).

Country	Dependent Variable	Independent Variable	Coefficient	Std. Error	*p*-Value	R^2
Bulgaria	SD	Const	1.9750	0.2650	<0.0001	0.751
		G_E	−0.0010	0.0002	0.0020	
		$G_{E(t-1)}$	−0.0011	0.0002	0.0007	
		$Tax_{EN(t-1)}$	0.0003	0.0001	0.0018	
		ETS_{EU}	0.0001	0.0001	0.0019	

Table 3. *Cont.*

Country	Dependent Variable	Independent Variable	Coefficient	Std. Error	p-Value	R^2
Czechia	SD	Const	0.6634	0.0419	<0.0001	0.377
		G_E	0.0001	0.0001	0.0219	
		R_S	−0.0045	0.0064	0.493	
Estonia	SD	Const	0.4221	0.0891	0.0008	0.604
		$P_{CO2(t-1)}$	0.0037	0.0015	0.0362	
		$RD_{(t-1)}$	0.0044	0.0014	0.0094	
		$ETS_{EU(t-1)}$	0.0001	0.0001	0.0228	
Poland	SD	Const	0.5630	0.0112	<0.0001	0.977
		R_S	0.0416	0.0019	<0.0001	
		P_{CO2}	0.0026	0.0004	<0.0001	

Source: own elaboration.

The estimation was carried out between the indicator of the sustainable development of energy sector enterprises, and the indicators of selected energy economy factors: government expenditure, environmental taxes, outlays on renewable energy sources, the prices of futures contracts for CO_2 emissions, outlays on R&D, and the EU Emissions Trading System in Bulgaria, Czechia, Estonia, and Poland from 2008 to 2022.

The models show different strengths and directions of relationships between the explained and explanatory variables.

The highest positive impact was recorded in Poland (the relation between the indicator of the sustainable development of energy sector enterprises and the indicator of outlays on renewable energy sources). The lowest positive impact was recorded in Bulgaria, Czechia, and Estonia (the relation between the indicator of the sustainable development of energy sector enterprises and the indicator of EU Emissions Trading System, Bulgaria, the indicator of government expenditure, Czechia, the previous period's indicator of EU Emissions Trading System, Estonia).

The highest negative impact was recorded in Czechia (the relation between the indicator of the sustainable development of energy sector enterprises and the indicator of outlays on renewable energy sources). The lowest negative impact was recorded in Bulgaria (the relation between the indicator of the sustainable development of energy sector enterprises and the indicator of government expenditure).

Table 4 presents the results of the VAR models in Bulgaria, Czechia, Estonia, and Poland from 2008 to 2022.

Model estimates were made in between the indicator of the sustainable development of energy sector enterprises and the indicator of the sustainable development of energy sector enterprises with lags in Bulgaria, Czechia, Estonia, and Poland from 2008 to 2022.

Models show different strengths of relationships between variables.

Table 4. Results of VAR models in the analyzed countries from 2008 to 2022.

Country	Dependent Variable	Independent Variable	Coefficient	Std. Error	p-Value	R^2
Bulgaria	SD	const	1.0386	0.2601	0.0025	0.304
		$SD_{(t-2)}$	−0.5497	0.2648	0.0646	
VAR system, lag order 2 OLS estimates, observations 2010–2022 (T = 13) Log-likelihood = 30.685217 Determinant of covariance matrix = 0.00052156345 AIC = −4.2593 BIC = −4.1289 HQC = −4.2861 Portmanteau test: LB(3) = 1.4794, df = 1 [0.2239]						

Table 4. *Cont.*

<table>
<tr><th>Country</th><th>Dependent Variable</th><th>Independent Variable</th><th>Coefficient</th><th>Std. Error</th><th>p-Value</th><th>R^2</th></tr>
<tr><td rowspan="2">Czechia</td><td rowspan="2">SD</td><td>const</td><td>0.4189</td><td>0.1722</td><td>0.0316</td><td rowspan="2">0.254</td></tr>
<tr><td>$SD_{(t-1)}$</td><td>0.4560</td><td>0.2254</td><td>0.0659</td></tr>
<tr><td colspan="7">VAR system, lag order 1
OLS estimates, observations 2009–2022 (T = 14)
Log-likelihood = 32.275822
Determinant of covariance matrix = 0.00058219287
AIC = −4.3251
BIC = −4.2338
HQC = −4.3336
Portmanteau test: LB(3) = 3.20801, df = 2 [0.2011]</td></tr>
<tr><td rowspan="2">Estonia</td><td rowspan="2">SD</td><td>const</td><td>0.3846</td><td>0.1275</td><td>0.0107</td><td rowspan="2">0.338</td></tr>
<tr><td>$SD_{(t-1)}$</td><td>0.4570</td><td>0.1847</td><td>0.0293</td></tr>
<tr><td colspan="7">VAR system, lag order 1
OLS estimates, observations 2009–2022 (T = 14)
Log-likelihood = 28.629623
Determinant of covariance matrix = 0.00098013206
AIC = −3.8042
BIC = −3.7129
HQC = −3.8127
Portmanteau test: LB(3) = 5.71858, df = 2 [0.0573]</td></tr>
<tr><td rowspan="2">Poland</td><td rowspan="2">SD</td><td>const</td><td>0.0323</td><td>0.0598</td><td>0.6015</td><td rowspan="2">0.946</td></tr>
<tr><td>$SD_{(t-2)}$</td><td>0.6801</td><td>0.2183</td><td>0.0110</td></tr>
<tr><td colspan="7">VAR system, lag order 2
OLS estimates, observations 2010–2022 (T = 13)
Log-likelihood = 37.36312
Determinant of covariance matrix = 0.0001866922
AIC = −5.2866
BIC = −5.1563
HQC = −5.3134
Portmanteau test: LB(3) = 7.07385, df = 1 [0.0078]</td></tr>
</table>

Source: own elaboration.

The highest positive impact of the explanatory variable into the dependent variable was recorded in Poland ($SD_{(t-2)}$), while the lowest was in Czechia ($SD_{(t-1)}$). The negative impact of the explanatory variable into the dependent variable was recorded only in Bulgaria.

Table 5 presents the results of the OLS estimation in Bulgaria, Czechia, Estonia, and Poland from 2008 to 2022.

Table 5. Results of OLS regressions in the analyzed countries from 2008 to 2022.

<table>
<tr><th>Country</th><th>Dependent Variable</th><th>Independent Variable</th><th>Coefficient</th><th>Std. Error</th><th>p-Value</th><th>R^2</th></tr>
<tr><td rowspan="11">Bulgaria</td><td rowspan="4">E</td><td>Const</td><td>−0.3612</td><td>0.2301</td><td>0.1447</td><td rowspan="4">0.984</td></tr>
<tr><td>R_S</td><td>0.0376</td><td>0.0064</td><td>0.0001</td></tr>
<tr><td>P_{CO2}</td><td>0.0019</td><td>0.0005</td><td>0.0039</td></tr>
<tr><td>S</td><td>1.1835</td><td>0.3211</td><td>0.0036</td></tr>
<tr><td rowspan="4">S</td><td>Const</td><td>0.5367</td><td>0.0146</td><td><0.0001</td><td rowspan="4">0.942</td></tr>
<tr><td>G_E</td><td>0.0001</td><td>0.0001</td><td>0.0531</td></tr>
<tr><td>P_{CO2}</td><td>−0.0009</td><td>0.0004</td><td>0.0374</td></tr>
<tr><td>E</td><td>0.3131</td><td>0.0205</td><td><0.0001</td></tr>
<tr><td rowspan="3">Env</td><td>Const</td><td>0.5296</td><td>0.2577</td><td>0.0623</td><td rowspan="3">0.947</td></tr>
<tr><td>RD</td><td>0.0069</td><td>0.0006</td><td><0.0001</td></tr>
<tr><td>ETS_{EU}</td><td>0.0001</td><td>0.0001</td><td>0.0408</td></tr>
</table>

Table 5. *Cont.*

Country	Dependent Variable	Independent Variable	Coefficient	Std. Error	p-Value	R^2
Czechia	E	Const	0.5061	0.1228	0.0021	0.958
		G_E	0.0001	0.0001	0.0002	
		ETS_{EU}	−0.0001	0.0001	<0.0001	
		S	0.0001	0.0001	<0.0001	
		Env	−0.4851	0.1539	0.0103	
	S	Const	0.6548	0.0385	<0.0001	0.936
		R_S	−0.0488	0.0050	<0.0001	
		P_{CO2}	−0.0043	0.0009	0.0009	
		RD	0.0001	0.0016	0.0067	
		E	0.0001	0.0570	<0.0001	
	Env	Const	0.0001	0.1826	0.0189	0.342
		G_E	0.0001	0.0000	0.0940	
		E	−0.2904	0.1671	0.0101	
		S	0.4125	0.2254	0.0945	
Estonia	E	Const	−0.9770	0.2266	0.0012	0.917
		Tax_{EN}	−0.0016	0.0005	0.0094	
		P_{CO2}	0.0071	0.0025	0.0151	
		S	2.1479	0.2830	<0.0001	
	S	Const	0.5100	0.0387	<0.0001	0.967
		Tax_{EN}	0.0009	0.0001	<0.0001	
		P_{CO2}	−0.0039	0.0007	0.0002	
		E	0.3909	0.0515	<0.0001	
	Env	Const	1.5725	0.2606	0.0001	0.759
		G_E	−0.0007	0.0002	0.0150	
		ETS_{EU}	−0.0001	0.0000	0.0011	
		E	1.0436	0.3920	0.0238	
		S	−1.6810	0.5987	0.0185	
Poland	E	Const	−0.3612	0.2301	0.0447	0.984
		R_S	0.0376	0.0064	0.0001	
		P_{CO2}	0.0019	0.0005	0.0039	
		S	1.1835	0.3211	0.0036	
	S	Const	0.5592	0.0200	<0.0001	0.932
		P_{CO2}	−0.0005	0.0003	0.0362	
		E	0.0001	0.0247	<0.0001	
	Env	Const	0.0001	0.2577	0.0623	0.947
		RD	0.0001	0.0006	<0.0001	
		ETS_{EU}	0.0001	0.0001	0.0408	

Source: own elaboration.

The variables explained in the estimation are the components of the sustainable development indicator of energy sector enterprises (the indicator of economic, social, and environmental development), while the explanatory variables are indicators of selected energy economy factors: government expenditure, environmental taxes, outlays on renewable energy sources, the prices of futures contracts for CO_2 emissions, outlays on R&D, and the EU Emissions Trading System, and the indicator of the economic, social, and environmental development of energy sector enterprises (depending on the type of model) in Bulgaria, Czechia, Estonia, and Poland from 2008 to 2022.

Models show the different strengths and directions of relationships between the explained and explanatory variables.

The estimation indicates a strong differentiation of the impact of individual variables of the selected energy economy factors on the economic, social, and environmental development of energy sector enterprises in Bulgaria, Czechia, Estonia, and Poland.

In all analyzed countries, the indicator of the economic development of energy sector enterprises is influenced by the social development of energy sector enterprises. The indicator of the social development of energy sector enterprises in all analyzed countries influenced the indicator of the prices of future contracts for CO_2 emissions. The indicator of the environmental development of energy sector enterprises in the analyzed countries (excluding Czechia) influenced the indicator of the EU Emissions Trading System.

The highest positive impact on the indicator of the economic development of energy sector enterprises is the indicator of the social development of energy sector enterprises (Estonia), while the lowest is the indicator of government expenditure and the indicator of the social development of energy sector enterprises (Czechia). The highest positive impact on the indicator of the social and environmental development of energy sector enterprises is the indicator of the economic development of energy sector enterprises (Estonia). The lowest positive impact on the indicator of the social development of energy sector enterprises is the indicator of government expenditure (Bulgaria), the indicator of outlays on renewable energy sources (Czechia), and the indicator of the economic development of energy sector enterprises (Czechia and Poland). The lowest positive impact on the indicator of the environmental development of energy sector enterprises is the indicator of government expenditure (Czechia), the indicator of outlays on R&D (Poland), and the indicator of the EU Emissions Trading System (Bulgaria and Poland).

The highest negative impact on the indicator of the economic development of energy sector enterprises is the indicator of the environmental development of energy sector enterprises (Czechia), while the lowest is the indicator of the EU Emissions Trading System (Czechia). The highest negative impact on the indicator of the social development of energy sector enterprises is the indicator of outlays on renewable energy sources (Czechia), while the lowest is the indicator of the prices of future contracts for CO_2 emissions (Poland). The highest negative impact on the indicator of the environmental development of energy sector enterprises is the indicator of the social development of energy sector enterprises (Estonia), while the lowest is the indicator of the EU Emissions Trading System (Estonia).

5. Discussion

The research results show a positive SD energy trend in the analyzed countries from 2008 to 2022, which confirms the analysis carried out so far [32,33,35,48]. It should be mentioned that this advancement is gradual, and we agree with the researchers who suggest that reforming the energy sector in developing countries is necessary, and that a suitable solution is to transform the sector with alternative and green energy sources [14,43,53].

The main research hypothesis is true because the impact of energy economy factors on SD is diversified in terms of strength and direction in the studied countries; moreover, these instruments should be used comprehensively, creating a coherent and effective system of supporting instruments of energy transformation. Our research confirms that previous analyses emphasized the complexity of SD and the diverse influence of factors on the level of implemented changes [10,15,16,40]. Presented models show that analyzed factors create a specific system supporting economic and ecological investments. Moreover, we believe they must be reformed and applied coherently and comprehensively [13,45,49].

We confirm the first sub-hypothesis because, in all analyzed countries, the economic development has higher growth dynamics; this is especially noticeable from 2020 to 2022, which could result from the coronavirus pandemic, the geopolitical situation, and rising energy prices. It is also affected by the structure of the energy balance of these countries and the great importance of hard coal for the energy sector. The E, S, and Env indicators verify that economic development is often prioritized in Eastern European countries, and environmental protection issues are less important [1,12,30,37,44]. There is a necessity for active efforts to develop renewable energy, transform energy, and introduce eco-innovations [9,26,34,44].

The second sub-hypothesis is true because, as the VAR models show, SD is progressive, and what is more, the results obtained in previous periods are a prerequisite for SD on an ongoing basis. Thus, we confirm the research results showing sustainable development's long-term and comprehensive nature [1,2,19,20,24,33].

We confirm the third sub-hypothesis because, according to the estimation of the simultaneous equation, the impact of energy factors on the pillars of sustainable development, economic, social and environmental, is varied. It verifies that SD requires a holistic approach, and that it is necessary to implement several economic instruments and legal regulations encouraging investment in developing human resources and environmental protection [15,44].

The presented models show that the economy has a statistically significant ($p < 0.05$) impact not only on reducing the emission of harmful substances into the natural environment, but also on economic and social development. There is a need to construct more comprehensive and responsible sustainable energy policies in the studied countries.

Countries should develop renewable energy sources and slowly implement environmentally friendly solutions. Energy policies should be coherent, with environmental goals. Moreover, funds from the European Union should be spent on developing renewable energy sources, such as photovoltaic panels and wind farms.

Implementing a coherent, clear, and transparent development system and support for renewable energy sources at the European Union level is necessary. Moreover, it is necessary to implement a mechanism that includes support instruments and a more efficient system of penalties for the emission of harmful substances.

These research results are important from the point of view of the legislation of the European Union. We consider that the general direction of energy development in the European Union is correct, but it is necessary to introduce a more efficient mechanism for controlling funds allocated to sustainable energy.

The direction of the development of economic instruments is correct and brings the first visible results, but it is important to concentrate on the evolution of instruments and to increase their effectiveness if necessary. The reforms should, in particular, focus on environmental taxes, which can play an increasingly important role and replace traditional fiscal sources supplying state budgets.

Our models have significant limitations, and the results are primarily influenced by the selection of analytical indicators, the methods of integration, and the estimation of model parameters.

6. Conclusions

The sustainable development of the energy sector is fundamental to the socioeconomic security of countries. It depends on several factors, both exogenous and endogenous. Our research shows that energy economy factors have a statistically significant impact on SD and its pillars in Bulgaria, Czechia, Estonia, and Poland. We also notice that this relationship is diversified in strength and direction.

Our contribution to the literature is the proprietary evolution of SD, through E, S, and Env factors, and the creation of the models which can be used to create an effective system of supporting instruments for energy transformation.

The research shows the necessity of reforming the European Union's energy policy and creating a more effective mechanism to support sustainable energy development. One of the goals should be to increase the importance of environmental taxes. Moreover, the authorities of the surveyed countries should consider the necessity of implementing innovative solutions in the energy field.

In further research, we will make a wider attempt to assess the remaining instruments influencing the sustainable development of enterprises, including macroeconomic conditions, social progress, and geopolitical conditions. We also want to analyze the relationships between variables in other European Union countries.

Author Contributions: A.M.: introduction, theoretical background, discussion and conclusions; M.K.: data collection, data transformation, calculations, discussion of tables and charts; A.F.-K.: abstract, supervision. All authors have read and agreed to the published version of the manuscript.

Funding: This research was carried out as a part of project no. POIR.01.01.01-00-0188/21-00, entitled: Predictive and adaptive METERNET-EnMS system for integrated control of environmental parameters and energy consumption in industrial and business processes (PA).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: https://ec.europa.eu/eurostat/databrowser/view/ENV_AC_AEINT_R2__custom_3251890/default/table?lang=en (accessed on 24 August 2022).

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

Abbreviations

G_E	Government expenditure
Tax_{EN}	Environmental taxes
R_S	Shares of primary energy from renewable sources
P_{CO2}	Prices of futures contracts for CO_2 emissions
RD	Outlays on R&D
ETS_{EU}	The EU Emissions Trading System
E	Economic development
S	Social development
Env	Environmental development
SD	Sustainable development

References

1. Pieloch-Babiarz, A.; Misztal, A.; Kowalska, M. An impact of macroeconomic stabilization on the sustainable development of manufacturing enterprises: The case of Central and Eastern European Countries. *Environ. Dev. Sustain.* **2021**, *23*, 8669–8698. [CrossRef]
2. Bąk, I.; Tarczyńska-Łuniewska, M.; Barwińska-Małajowicz, A.; Hydzik, P.; Kusz, D. Is Energy Use in the EU Countries Moving toward Sustainable Development? *Energies* **2022**, *15*, 6009. [CrossRef]
3. Liu, Y.; Xiong, R.; Lv, S.; Gao, D. The Impact of Digital Finance on Green Total Factor Energy Efficiency: Evidence at China's City Level. *Energies* **2022**, *15*, 5455. [CrossRef]
4. Muñoz-Torres, M.J.; Fernández-Izquierdo, M.Á.; Rivera-Lirio, J.M.; Ferrero-Ferrero, I.; Escrig-Olmedo, E. Sustainable supply chain management in a global context: A consistency analysis in the textile industry between environmental management practices at company level and sectoral and global environmental challenges. *Environ. Dev. Sustain.* **2021**, *23*, 3883–3916. [CrossRef]
5. Li, X.; Yu, Z.; Salman, A.; Ali, Q.; Hafeez, M.; Aslam, M.S. The role of financial development indicators in sustainable development-environmental degradation nexus. *Environ. Sci. Pollut. Res.* **2021**, *28*, 33707–33718. [CrossRef]
6. Gleißner, W.; Günther, T.; Walkshäusl, C. Financial sustainability: Measurement and empirical evidence. *J. Bus. Econ.* **2022**, *92*, 467–516. [CrossRef]
7. Gonçalves, A.; Silva, C. Looking for Sustainability Scoring in Apparel: A Review on Environmental Footprint, Social Impacts and Transparency. *Energies* **2021**, *14*, 3032. [CrossRef]
8. Sáez-Martínez, F.J.; Díaz-García, C.; González-Moreno, Á. Factors Promoting Environmental Responsibility in European SMEs: The Effect on Performance. *Sustainability* **2016**, *8*, 898. [CrossRef]
9. Xu, Z.; Yen, N.; Sugumaran, V. Editorial: Special Issue on Multi-modal Information mining and Analytics for Environmental Technology & Innovation. *Environ. Technol. Innov.* **2022**, *28*, 102560. [CrossRef]
10. Wang, Q.; Jiang, R.; Zhan, L. Is decoupling economic growth from fuel consumption possible in developing countries?—A comparison of China and India. *J. Clean. Prod.* **2019**, *229*, 806–817. [CrossRef]
11. Wójcik-Jurkiewicz, M.; Czarnecka, M.; Kinelski, G.; Sadowska, B.; Bilińska-Reformat, K. Determinants of Decarbonisation in the Transformation of the Energy Sector: The Case of Poland. *Energies* **2021**, *14*, 1217. [CrossRef]
12. Ciesielska-Maciągowska, D.; Klimczak, D.; Skrzek-Lubasińska, M. Central and Eastern European CO_2 Market—Challenges of Emissions Trading for Energy Companies. *Energies* **2021**, *14*, 1051. [CrossRef]
13. Fan, Y.V.; Pintarič, Z.N.; Klemeš, J.J. Emerging Factors for Energy System Design Increasing Economic and Environmental Sustainability. *Energies* **2020**, *13*, 4062. [CrossRef]

14. Taghizadeh-Hesary, F.; Yoshino, N. Sustainable Solutions for Green Financing and Investment in Renewable Energy Projects. *Energies* **2020**, *13*, 788. [CrossRef]
15. Nakano, M.; Managi, S. Regulatory reforms and productivity: An empirical analysis of the Japanese electricity industry. *Energy Policy* **2008**, *36*, 201–209. [CrossRef]
16. Nakano, M.; Managi, S. Productivity analysis with CO_2 emissions in Japan. *Pac. Econ. Rev.* **2010**, *15*, 708–718. [CrossRef]
17. Bigerna, S.; D'Errico, M.C.; Polinori, P. Environmental and energy efficiency of EU electricity industry: An almost spatial two stages. DEA approach. *Energy J.* **2019**, *40*. Available online: https://ideas.repec.org/a/aen/journl/ej40-si1-d\T1\textquoterighterrico.html (accessed on 20 July 2022). [CrossRef]
18. Fonseca, L.M.; Domingues, J.P.; Dima, A.M. Mapping the Sustainable Development Goals Relationships. *Sustainability* **2020**, *12*, 3359. [CrossRef]
19. Fuso Nerini, F.; Sovacool, B.; Hughes, N.; Cozzi, L.; Cosgrave, E.; Howells, M.; Tavoni, M.; Tomei, J.; Zerriffi, H.; Milligan, B. Connecting climate action with other Sustainable Development Goals. *Nat. Sustain.* **2019**, *2*, 674–680. [CrossRef]
20. Comporek, M.; Kowalska, M.; Misztal, A. Macroeconomic stability and transport companies' sustainable development in the Eastern European Union. *J. Bus. Econ. Manag.* **2022**, *23*, 131–144. [CrossRef]
21. Hahn, R.; Kühnen, M. Determinants of sustainability reporting: A review of results, trends, theory, and opportunities in an expanding field of research. *J. Clean. Prod.* **2013**, *59*, 5–21. [CrossRef]
22. Elkington, J. *Cannibals with Forks–Triple Bottom Line of 21st Century Business*; New Society Publishers: Gabriola Island, BC, Canada; Stony Creek, CT, USA, 1997.
23. Dyllick, T.; Hockerts, K. Beyond the Business Case for Corporate Sustainability. *Bus. Strategy Environ.* **2002**, *11*, 130–141. [CrossRef]
24. Lozano, R. Developing collaborative and sustainable organizations. *J. Clean. Prod.* **2008**, *16*, 499–509. [CrossRef]
25. Bansal, S.; Garg, I.; Sharma, G.D. Social entrepreneurship as a path for social change and driver of sustainable development: A systematic review and research agenda. *Sustainability* **2019**, *11*, 1091. [CrossRef]
26. Tolstykh, T.; Gamidullaeva, L.; Shmeleva, N. Elaboration of a Mechanism for Sustainable Enterprise Development in Innovation Ecosystems. *J. Open Innov. Technol. Mark. Complex.* **2020**, *6*, 95. [CrossRef]
27. Zorina, T.G. Ustoychivoye razvitiye energetiki: Sushchnost i metodicheskiye podkhody k otsenke. *Sovrem. Tekhnologii Upr.* **2015**, *1*, 4905.
28. Hassan, A.; Ibrahim, M.; Bala, A.J. On the pursuit of energy security: Evidence from the nexus between clean energy stock price and energy security elements. *Int. J. Sustain. Energy* **2022**, *41*, 846–867. [CrossRef]
29. Standar, A.; Kozera, A.; Jabkowski, D. The Role of Large Cities in the Development of Low-Carbon Economy—The Example of Poland. *Energies* **2022**, *15*, 595. [CrossRef]
30. Stamatakis, E.; Perwög, E.; Garyfallos, E.; Millán, M.S.; Zoulias, E.; Chalkiadakis, N. Hydrogen in Grid Balancing: The European Market Potential for Pressurized Alkaline Electrolyzers. *Energies* **2022**, *15*, 637. [CrossRef]
31. Misztal, A.; Kowalska, M.; Fajczak-Kowalska, A.; Strunecky, O. Energy Efficiency and Decarbonization in the Context of Macroeconomic Stabilization. *Energies* **2021**, *14*, 5197. [CrossRef]
32. Greene, D.L. *Measuring Energy Sustainability*; MIT Press: Cambridge, MA, USA, 2009; pp. 354–373.
33. Resniova, E.; Ponomarenko, T. Sustainable Development of the Energy Sector in a Country Deficient in Mineral Resources: The Case of the Republic of Moldova. *Sustainability* **2021**, *13*, 3261. [CrossRef]
34. Wit, B.; Dresler, P.; Surma-Syta, A. Innovation in Start-Up Business Model in Energy-Saving Solutions for Sustainable Development. *Energies* **2021**, *14*, 3583. [CrossRef]
35. Kolosok, S.; Bilan, Y.; Vasylieva, T.; Wojciechowski, A.; Morawski, M. A Scoping Review of Renewable Energy, Sustainability and the Environment. *Energies* **2021**, *14*, 4490. [CrossRef]
36. Simionescu, M.; Wojciechowski, A.; Tomczyk, A.; Rabe, M. Revised Environmental Kuznets Curve for V4 Countries and Baltic States. *Energies* **2021**, *14*, 3302. [CrossRef]
37. Simionescu, M.; Bilan, Y.; Zawadzki, P.; Wojciechowski, A.; Rabe, M. GHG Emissions Mitigation in the European Union Based on Labor Market Changes. *Energies* **2021**, *14*, 465. [CrossRef]
38. Khaled, R.; Ali, H.; Mohamed, E.K.A. The Sustainable Development Goals and corporate sustainability performance: Mapping, extent and determinants. *J. Clean. Prod.* **2021**, *311*, 127599. [CrossRef]
39. Ragazou, K.; Passas, I.; Garefalakis, A.; Zafeiriou, E.; Kyriakopoulos, G. The Determinants of the Environmental Performance of EU Financial Institutions: An Empirical Study with a GLM Model. *Energies* **2022**, *15*, 5325. [CrossRef]
40. Ali, S.; Akter, S.; Ymeri, P.; Fogarassy, C. How the Use of Biomass for Green Energy and Waste Incineration Practice Will Affect GDP Growth in the Less Developed Countries of the EU (A Case Study with Visegrad and Balkan Countries). *Energies* **2022**, *15*, 2308. [CrossRef]
41. Greyson, J. An economic instrument for zero waste, economic growth and sustainability. *J. Clean. Prod.* **2007**, *15*, 1382–1390. [CrossRef]
42. Płonka, A.; Dacko, M.; Satoła, Ł.; Dacko, A. The Idea of Sustainable Development and the Possibilities of Its Interpretation and Implementation. *Energies* **2022**, *15*, 5394. [CrossRef]
43. Kuo, F.I.; Fang, W.T.; LePage, B.A. Proactive environmental strategies in the hotel industry: Eco-innovation, green competitive advantage, and green core competence. *J. Sustain. Tour.* **2022**, *30*, 1240–1261. [CrossRef]
44. Costantini, V.; Crespi, F.; Marin, G.; Paglialunga, E. Eco-innovation, sustainable supply chains and environmental performance in European industries. *J. Clean. Prod.* **2017**, *155*, 141–154. [CrossRef]

45. Ferreira, L.J.; Dias, L.P.; Liu, J. Adopting Carbon Pricing Factors at the Local Level: A City Case Study in Portugal. *Sustainability* **2022**, *14*, 1812. [CrossRef]
46. Kadria, M.; Farhani, S.; Guirat, Y. Investigating the Relationships between Renewable Energy Consumption, Socio-Economic Factors and Health: A PVAR Analysis from MENA Net Oil Importing Countries. *Sustainability* **2022**, *14*, 151. [CrossRef]
47. Bailey, I.; Ditty, C. Energy markets, capital inertia and economic instrument impacts. *Clim. Policy* **2009**, *9*, 22–39. [CrossRef]
48. Wu, S.; Pan, Q. Economic Growth in Emerging Market Countries. *Glob. J. Emerg. Mark. Econ.* **2021**, *13*, 192–215. [CrossRef]
49. Gunningham, N. *Regulation, Economic Instruments and Sustainable Energy*; RegNet Research Paper No. 2014/29; John Wiley & Sons: New York, NY, USA, 2014. [CrossRef]
50. Kim, H.H.; Lee, D.J.; Kim, K.T.; Park, S.J. Measuring the Efficiency of Investment in the Deployment and Technology Development of Renewable Energy in Korea Using the DEA. *J. Korean Inst. Ind. Eng.* **2014**, *40*, 358–365. [CrossRef]
51. Stankowska, A. Sustainability Development: Assessment of Selected Indicators of Sustainable Energy Development in Poland and in Selected EU Member States Prior to COVID-19 and Following the Third Wave of COVID-19. *Energies* **2022**, *15*, 2135. [CrossRef]
52. Saraswat, S.K.; Digalwar, A.K. Evaluation of energy alternatives for sustainable development of energy sector in India: An integrated Shannon's entropy fuzzy multi-criteria decision approach. *Renew. Energy* **2021**, *171*, 58–74. [CrossRef]
53. Akadiri, S.S.; Adebayo, T.S. Asymmetric nexus among financial globalization, non-renewable energy, renewable energy use, economic growth, and carbon emissions: Impact on environmental sustainability targets in India. *Environ. Sci. Pollut. Res.* **2022**, *29*, 16311–16323. [CrossRef]
54. Li, Q.; Cherian, J.; Shabbir, M.S.; Sial, M.S.; Li, J.; Mester, I.; Badulescu, A. Exploring the Relationship between Renewable Energy Sources and Economic Growth. The Case of SAARC Countries. *Energies* **2021**, *14*, 520. [CrossRef]
55. Nieto, J.; Carpintero, Ó.; Lobejón, L.F.; Miguel, L.J. An ecological macroeconomics model: The energy transition in the EU. *Energy Policy* **2020**, *145*, 111726. [CrossRef]
56. Kwiatkowski, D.; Phillips, P.C.B.; Schmidt, P.; Shin, Y. Testing the null hypothesis of stationarity against the alternative of a unit root. *J. Econom.* **1992**, *54*, 159–178. [CrossRef]