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

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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 CO2 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

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: GE, environmental taxes: TaxEN, 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 \( G_E \), \( Tax_{\text{EN}} \), \( R_S \), \( P_{\text{CO2}} \), RD, and \( \text{ETS}_{\text{EU}} \) 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: \( 8930.11 \text{ g per euro} \)) [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, hydrofluorocarbons (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:
       \[
       F_{ij} = \frac{x_{ij}}{\max_i \{x_{ij}\}}, \quad F_{ij} \in [0; 1] \tag{1}
       \]
     - For the destimulants:
       \[
       F_{ij} = \frac{\min_i \{x_{ij}\}}{x_{ij}}, \quad F_{ij} \in [0; 1] \tag{2}
       \]
   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:

\[
SD_i = \frac{\sum_{j=1}^{n} F_{ij}}{n}, \quad (i = 1, 2, \ldots, n)
\]

where: SDi 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:

\[
SD_i = \beta_0 + \beta_1 G_{Ei} + \beta_2 G_{Ei-1} + \beta_3 Tax_{ENi} + \beta_4 Tax_{ENi-1} + \beta_5 R_{Si} + \beta_6 R_{Si-1} + \beta_7 P_{CO2i} + \beta_8 P_{CO2i-1} + \beta_9 RD_i + \beta_{10} RD_{i-1} + \beta_{11} ETS_{EUi} + \beta_{12} ETS_{EUi-1} + \epsilon_i = SD_i + \epsilon_i
\]

The residual for each observation is as follows:

\[
\epsilon_i = SD_i - \hat{SD}_i
\]

where \(\beta_0\) is the intercept, \(\beta_1, \ldots, \beta_{12}\) is the slope; \(\epsilon_i\) 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]:

\[
B_0 SD_i = c_0 + B_1 SD_{i-1} + \cdots + B_p SD_{i-p} + \epsilon_i
\]

where \(c_0\) is a \(k \times 1\) vector of constants, \(B_i\) is a \(k \times k\) matrix (for every \(i = 0, \ldots, p\)) and \(\epsilon_i\) is a \(k \times 1\) vector of error terms. The main diagonal terms of the \(B_0\) matrix (the coefficients on the \(i\)-th variable in the \(i\)-th equation) are scaled to 1.

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

\[
\begin{align*}
E &= \beta_0 + \beta_1 G_{Ei} + \beta_2 Tax_{ENi} + \beta_3 R_{Si} + \beta_4 P_{CO2i} + \beta_5 RD_i + \beta_6 ETS_{EUi} + \beta_7 E_i + \beta_8 Env_i + \epsilon_i \\
S &= \beta_0 + \beta_1 G_{Ei} + \beta_2 Tax_{ENi} + \beta_3 R_{Si} + \beta_4 P_{CO2i} + \beta_5 RD_i + \beta_6 ETS_{EUi} + \beta_7 E_i + \beta_8 Env_i + \epsilon_i \\
Env &= \beta_0 + \beta_1 G_{Ei} + \beta_2 Tax_{ENi} + \beta_3 R_{Si} + \beta_4 P_{CO2i} + \beta_5 RD_i + \beta_6 ETS_{EUi} + \beta_7 E_i + \beta_8 Env_i + \epsilon_i
\end{align*}
\]

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.
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.
Outlays on renewable energy sources

- Bulgaria = 0.4794 t + 4.3258
  \( R^2 = 0.7434 \)
- Estonia = 0.4794 t + 4.3258
  \( R^2 = 0.7434 \)
- Czechia = 0.254 t + 2.5227
  \( R^2 = 0.8322 \)
- Poland = 0.3327 t + 2.3435
  \( R^2 = 0.9118 \)

Prices of futures contracts for CO2 emissions

- Bulgaria, Czechia, Estonia, Poland = 0.3131 t + 10.48
  \( R^2 = 0.0407 \)
- Bulgaria = 0.0271 t + 0.1966
  \( R^2 = 0.2088 \)
- Czechia = 0.8042 t + 2.3893
  \( R^2 = 0.5443 \)
- Estonia = 1.1391 t + 2.2389
  \( R^2 = 0.5036 \)
- Poland = 2.717 t - 6.3007
  \( R^2 = 0.8673 \)

Outlays on R&D

- Bulgaria = 0.0271 t + 0.1966
  \( R^2 = 0.2088 \)
- Estonia = 1.1391 t + 2.2389
  \( R^2 = 0.5036 \)
- Poland = 2.717 t - 6.3007
  \( R^2 = 0.8673 \)
- Czechia = 0.8042 t + 2.3893
  \( R^2 = 0.5443 \)

**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.

| Country | 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|
|         | GE        | 351.30 | 356.10 | 61.00             | 420.62| 252.10 |
|         | TaxEN     | 175.18 | 109.46 | 162.64            | 431.00| 11.91 |
|         | RS        | 8.16 | 9.00   | 2.40              | 11.52| 3.40|
|         | PCO2      | 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|
|         | GE        | 1712.39 | 1796.40 | 287.00           | 2143.70| 1024.90 |
|         | TaxEN     | 301.16 | 229.26  | 185.77            | 652.00| 124.07 |
|         | Rs        | 4.55 | 4.95   | 1.20              | 6.33| 1.93|
|         | PCO2      | 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 | 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 |
|         | GE        | 139.28| 158.30 | 74.10              | 215.36|−38.10 |
|         | TaxEN     | 65.55 | 52.17  | 37.76              | 139.18|29.36 |
|         | Rg        | 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 |

| Country | Indicator | Mean  | Median | Standard Deviation | Max  | Min  |
|---------|-----------|-------|--------|--------------------|------|------|
| 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 |
|         | GE        | 2429.38| 2475.59 | 295.51             | 2859.10|1783.30 |
|         | TaxEN     | 165.94| 138.94 | 67.28              | 286.00|81.81 |
|         | Rg        | 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/GE | 0.1320 | 0.2607 | 0.1810 | 0.1810 |
| | SD/TAX | 0.1846 | 0.4143 | 0.2952 | 0.2952 |
| | SD/Rs | -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/GE | 0.5927 | 0.6571 | 0.5429 | 0.5429 |
| | SD/TAX | 0.3084 | 0.2643 | 0.1810 | 0.1810 |
| | SD/Rs | 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/GE | 0.2078 | 0.2643 | 0.1619 | 0.1619 |
| | SD/TAX | 0.4529 | 0.3357 | 0.2952 | 0.2952 |
| | SD/Rs | 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/GE | 0.1892 | 0.2536 | 0.1619 | 0.1619 |
| | SD/TAX | 0.8739 | 0.8464 | 0.6381 | 0.6381 |
| | SD/Rs | 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 |
| | | GE | -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 | R²   |
|----------|--------------------|----------------------|-------------|-----------|---------|------|
| Czechia  | SD                 | Const                | 0.6634      | 0.0419    | <0.0001 | 0.377|
|          |                    | GE                   | 0.0001      | 0.0001    | 0.0219  |      |
|          |                    | RS                   | -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|
|          |                    | RS                   | 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 CO₂ 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 | R²  |
|----------|--------------------|----------------------|-------------|-----------|---------|-----|
| 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.

| Country | Dependent Variable | Independent Variable | Coefficient | Std. Error | p-Value | R² |
|---------|-------------------|----------------------|-------------|-----------|---------|----|
| Czechia | SD                | const                | 0.4189      | 0.1722    | 0.0316  | 0.254 |
|         |                   | SD(t−1−1)           | 0.4560      | 0.2254    | 0.0659  |     |

VAR system, lag order 1
OLS estimates, observations 2009–2022 (T = 14)
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]

| Estonia | SD                | const                | 0.3846      | 0.1275    | 0.0107  | 0.338 |
|         |                   | SD(t−1−1)           | 0.4570      | 0.1847    | 0.0293  |     |

VAR system, lag order 1
OLS estimates, observations 2009–2022 (T = 14)
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]

| Poland  | SD                | const                | 0.0323      | 0.0598    | 0.6015  | 0.946 |
|         |                   | SD(t−1−2)           | 0.6801      | 0.2183    | 0.0110  |     |

VAR system, lag order 2
OLS estimates, observations 2010–2022 (T = 13)
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]

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−1−1)). 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.

| Country | Dependent Variable | Independent Variable | Coefficient | Std. Error | p-Value | R² |
|---------|-------------------|----------------------|-------------|-----------|---------|----|
| Bulgaria | E                | Const                | −0.3612     | 0.2301    | 0.1447  | 0.984 |
|         |                   | RS                   | 0.0376      | 0.0664    | 0.0001  |     |
|         |                   | P_CO2                | 0.0019      | 0.0005    | 0.0039  |     |
|         |                   | S                    | 1.1835      | 0.3211    | 0.0036  |     |
|         |                   | Const                | 0.5367      | 0.0146    | <0.0001 |     |
|         |                   | GE                   | 0.0001      | 0.0001    | 0.0531  |     |
|         |                   | P_CO2                | −0.0009     | 0.0004    | 0.00374 |     |
|         |                   | E                    | 0.3131      | 0.0205    | <0.0001 |     |
| Env     | E                 | Const                | 0.5296      | 0.2577    | 0.0623  | 0.947 |
|         |                   | RD                   | 0.0069      | 0.0006    | <0.0001 |     |
|         |                   | ETS_EU               | 0.0001      | 0.0001    | 0.0408  |     |
Table 5. Cont.

| Country | Dependent Variable | Independent Variable | Coefficient  | Std. Error | p-Value  | R²  |
|---------|--------------------|----------------------|--------------|-----------|----------|-----|
| Czechia | E                  | Const                | 0.5061       | 0.1228    | 0.0021   |     |
|         |                    | GE                   | 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   | 0.958|
|         | S                  | Const                | 0.6548       | 0.0385    | <0.0001  |     |
|         |                    | RS                   | −0.0488      | 0.0050    | <0.0001  | 0.936|
|         |                    | IPCC                 | −0.0043      | 0.0009    | 0.0009   |     |
|         |                    | RD                   | 0.0001       | 0.0016    | 0.0067   |     |
|         |                    | E                    | 0.0001       | 0.0570    | <0.0001  |     |
| Estonia | Env                | Const                | 0.0001       | 0.1826    | 0.0189   | 0.342|
|         |                    | GE                   | 0.0001       | 0.0000    | 0.0940   |     |
|         |                    | E                    | −0.2904      | 0.1671    | 0.0101   |     |
|         |                    | S                    | 0.4125       | 0.2254    | 0.0945   |     |
|         | S                  | Const                | −0.9770      | 0.2266    | 0.0012   | 0.917|
|         |                    | Tax_EN               | −0.0016      | 0.0005    | 0.0094   |     |
|         |                    | IPCC                 | 0.0071       | 0.0025    | 0.0151   |     |
|         |                    | S                    | 2.1479       | 0.2830    | <0.0001  |     |
|         | Env                | Const                | 0.5100       | 0.0387    | <0.0001  | 0.967|
|         |                    | Tax_EN               | 0.0009       | 0.0001    | <0.0001  |     |
|         |                    | IPCC                 | 0.0039       | 0.0007    | <0.0001  |     |
|         |                    | E                    | 0.3909       | 0.0515    | <0.0001  |     |
|         | Env                | Const                | 1.5725       | 0.2606    | 0.0001   | 0.759|
|         |                    | GE                   | −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|
|         |                    | RS                   | 0.0376       | 0.0064    | 0.0001   |     |
|         |                    | IPCC                 | 0.0019       | 0.0005    | 0.0039   |     |
|         |                    | S                    | 1.1835       | 0.3211    | 0.0036   |     |
|         | S                  | Const                | 0.5592       | 0.0200    | <0.0001  | 0.932|
|         |                    | IPCC                 | −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 CO₂ 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\textsubscript{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\textsubscript{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 coun-
tries, 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 condi-
tions, social progress, and geopolitical conditions. We also want to analyze the relationships between variables in other European Union countries.

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Abbreviations

| Abbreviation | Description |
|--------------|-------------|
| GE           | Government expenditure |
| TaxEN        | Environmental taxes |
| RS           | Shares of primary energy from renewable sources |
| PCO2         | Prices of futures contracts for CO2 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 |

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