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MODELING THE OIL PRICE INFLUENCES UPON THE ENERGY SECTOR IN THE MACROECONOMIC CONTEXT. EMPIRICAL EVIDENCE FROM CENTRAL AND EASTERN EUROPEAN COUNTRIES

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Abstract: The oil price influences and tendencies have gained, lately major developments both at the European level and on the international level. Moreover, several interconnections between the energy sector and oil price influences have become the panacea of several important research and studies. In this article, we provide a qualitative and quantitative

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approach to the interconnections manifested between oil price movements and the developments of the energy sector. The study is focused on Central and Eastern European Countries which have similarities and differences both at the energy sector level and economy level. The econometric techniques used in this study reveal the importance of the causality relationship between oil price movements and the energy sector taking into account the macroeconomic context. The conclusions of this study highlight some important fine-tuning aspects that must be recalibrated in Central and Eastern European Countries to increase the economic outcomes, strengthen the energy sector, and respond properly to the oil price movement trends.

Keywords: Oil price; energy consumption; macroeconomic variables; economic modeling; economic outcomes.

JEL Codes: O13, Q43.

1. Introduction

This paper aims to study the impact of oil prices on the energy sector in Central and Eastern European (CEE) countries within a macroeconomic context. Fluctuations in oil prices can have a substantial impact on the cost of energy production, transportation, and consumption in these countries. As a result, changes in oil prices can influence inflation rates, trade balances, fiscal policies, and overall economic growth in the region.

This paper pursues the interconnections manifested between oil price movements and the developments of the energy sector in CEE countries. The article aims to study the economic factors that influence independence and energy security given the international geopolitical context, as political instability and economic uncertainty increase, the need for enhancing the independence and security of the energy sector becomes a priority for governments. Therefore, the researched topic is important for governments, national and international institutions specialized in the energy field, and academia due to the significance of the energy sector in the economic development and social welfare of countries.

The topic is of great actuality in the context of global energy objectives to reduce fossil fuels and gas emissions and promote social and environmental responsibility and renewable energy. The subject of oil price volatility and the energy sector were approached in the theoretical and empirical literature to a great extent, especially in the last years due to the new climate and environmental paradigm. We believe that the topic is worth researching in the new socio-economic and political environment of Europe, our purpose is to deepen the understanding and knowledge regarding the situation of CEE countries.

The empirical study expands the research of energy security in CEE countries and provides some insights regarding the nexus between oil price movements and the energy sector. We provide a qualitative and quantitative approach using econometric techniques to analyze the causality relationship between energy supply and final consumption, as a dependent variable, and inflation, oil rents, imports and exports of energy, and general government deficit, as the independent variable. The empirical findings of this study reveal that the most important determining factors of energy supply and final consumption are imports and exports of energy, suggesting that the governments of CEE countries must pay close attention to commercial balance.

The article is structured in several sections. The first section introduces the topic and the aim of the research. The second section synthesized the literature review related to the topic approached. The third section presents the research methodology, data, and research method used in the study. The fourth section shows the empirical results, and the fifth section is dedicated to the discussion of the findings and recommendations. The last section exposed the conclusions of the paper.

2. Literature review

The last decades were marked by a shift towards sustainable energy development, with the energy sector becoming a priority in economic policy for many countries. The studies of Sequeira & Santos (2018), and Chen, Pinar & Stengos (2021) show that more democratic countries tend to invest more in renewable energy transition. Also, Cengiz & Manga (2023) established that participatory democracy and globalization have a positive impact on renewable energy consumption.

The study by Cadoret & Padovano (2016) found no evidence that political regimes influence the renewable energy sector, nor that environmental taxes have a positive correlation to renewable energy development. Duparc-Portier & Figus (2024) observed that fiscal policies influence energy prices and showed that policies oriented toward regulating energy demand will support welfare and economic growth.

Hasan, Nan & Waris (2024) researched institutional quality, oil consumption, and ecological footprint, proving that improving institutional quality could enhance environmental sustainability. Zhou & Li (2022) noted that trade openness and human capital development enhance energy consumption. Also, the results of Han, Pu & Wu (2023) show that the trade of green energy improves economic growth and regional cohesion in CEE countries.

The research of Owjimehr, Meybodi & Jamshidi (2023) highlighted that geopolitical risk has a positive impact on energy efficiency. Also, Khan, Khurshid & Cifuentes-Faura (2023) show that geopolitical risks have a significant positive impact on

economic security in CEE countries, enhancing the need for policies that prioritize democracy and social cohesion, and reduce inequality and instability.

Olmo, Salaheddine & Moya-Fernández (2020) delved into regional cohesion showing that renewable energy consumption in neighboring countries will lead to synergies between countries and will promote sustainable socio-economic development. The findings of Nguyen & Kakinaka (2018) emphasize the need for effective energy policies that encourage the transition from fuel to renewable energy sources, especially in less developed countries.

Brodny & Tutak (2021) made a ranking of sustainable energy development in CEE countries, showing that Latvia and Croatia are best placed, while Poland and Bulgaria had the lowest ranking position. Jonek-Kowalska (2022) made a multicriteria analysis of energy policy implementation in CEE countries and found that the most efficient way to transform energy is through the diversification of energy sources. At the same time, the research of Brodny & Tutak (2023) assesses the energy security of European countries and advocates the need for energy independence by developing renewable energy sources and nuclear energy. The findings of Gritz & Wolff (2024) also support the need for policies to support the integrity of the European energy market.

The study of Fedajev et al. (2023) enhanced the role of infrastructure and renewable energy in industrial and economic development in CEE, showing the energy sector plays a crucial role in the economy and holds significant political interest. Also, Klimek et al. (2024) highlight the need for adequate energy infrastructure, especially in CEE countries.

Belaïd (2022) increases awareness that the energy prices and the green transition can exacerbate the energy poverty trap in Europe if climate policies are not designed to reduce inequality and energy poverty. The findings of Karpinska & Śmiech (2020) show that on average, 23.57% of the population of CEE countries is exposed to energy poverty.

The studies of Wang et al. (2022), and Chen et al. (2024) established the negative effects of international geopolitical risk and global economic policy uncertainty on oil prices in the international market. Alola, Adekoya & Oliyide (2022) found a causal relationship between energy security and crude oil price volatility. The findings of Jawadi, Cheffou & Bu (2023) show that oil price change exerts a significant effect on the real economy and financial sectors.

Oil price volatility has a negative impact on inflation and exchange rates (Bigerna, 2024), industrial financial expenditure (Guo, Zhang & Iqbal, 2024), financial markets and environment (Yang, Li & Sui, 2023), tourism sector (Feng, Sun & Li, 2022). Cuestas & Gil-Alana (2018) observed that oil price shocks have a significant impact on the natural rate of unemployment in the long term. Jabri, Raghavan &

Vespignani (2022) found that oil price shocks have a significant influence on real GDP and could lead to fiscal reforms (Agboola, Chowdhury & Yang, 2024). On the contrary, the overall results obtained by Mohanty, Nandha & Bota (2010) indicate no significant association between oil price and stock market returns.

Most recent studies examined the influence of oil prices on renewable energy and concluded that oil prices have a significant impact on the energy sector (Shah, Hiles & Morley, 2018; Magazzino & Giolli, 2024). The results of Omri & Nguyen (2014), Mukhtarov et al. (2022), and Nchofoung (2024) support the negative influence of increasing oil prices on energy consumption. On the contrary, Wang, Li & Pisarenko (2020), and Zaghdoudi et al. (2023) found that oil prices have a positive impact on renewable energy.

Table 1 illustrates the previous empirical studies related to the relationship between oil price dynamics and the energy sector.

Table 1 Previous empirical studies regarding the oil price movements and the energy sector

Author	Research purpose	Research method	Results
Omri & Nguyen (2014)	To study the determining factors of renewable energy consumption.	Dynamic system-GMM panel model	Increasing oil prices has a negative influence on renewable energy consumption.
Shah, Hiles & Morley (2018)	To explore the relationship established between renewable energy investment, oil prices, GDP, and the interest rate in Norway, the UK, and the USA.	VAR model	There is a strong relationship between oil prices and renewable energy in the USA and Norway, but no relationship in the UK.
Wang, Li & Pisarenko (2020)	To investigate the driving factors of renewable energy and the effect of oil prices on renewable energy consumption.	Multiple co-integration estimation approaches	Energy intensity, oil price, R&D investment, and policy all have a positive impact on renewable energy.
Xu, Fu & Lau (2021)	To study the impact of global energy uncertainty on oil prices.	Factor Augmented Vector Autoregression model	Real oil prices are very sensitive to aggregate energy market uncertainty shocks.
Mukhtarov et al. (2022)	To evaluate the effect of higher oil prices, CO2 emissions, and	General to Specific (Gets) modeling approach	Oil prices and CO2 emissions have a statistically significant

	income on renewable energy consumption in Iran.		negative impact on renewable energy consumption.
Alola, Ozkan, Usman (2023)	To research the influence of energy security on oil prices in the USA.	Kernel-Based Regularized Least Squares (KRLS) and quantile regression	Energy security has a significant influence on oil prices.
Alola, Ozkan, Usman (2023)	To examine the dynamics of oil prices among energy demand in the USA.	Multivariate Quantile regression and Kernel-based Regularized Least Squares (KRLS)	Energy demand has a non-linear positive effect on crude oil prices in the USA, but retail electricity prices have a non-linear negative effect on crude oil prices.
Zaghdoudi et al. (2023)	To investigate the effects of oil price shocks on renewable energy consumption in China.	Fourier nonlinear ARDL model	The oil price-renewable energy consumption relationship is nonlinear, but the increase in oil price determines the increase in renewable energy consumption.
Magazzino & Giolli (2024)	To analyze the relationship between oil prices and renewable energy sources in Italy.	Quantile and wavelet analysis	A strong correlation between oil prices and renewable energy sources during the COVID-19 pandemic.
Zhang & Guo (2024)	To assess if the energy uncertainty affects the oil price volatility forecasting.	Double Asymmetric GARCH-MIDAS-EUI model	Energy uncertainty can influence crude oil market volatility and capture more relevant and valid information about future price volatility.
Nchofoung (2024)	To delve into the effects of oil price shocks on renewable energy transition in Africa.	Driscoll and Kraay and Panel VAR regression	Oil price shocks have a significant negative influence on renewable energy transition in oil-exporting countries and do not affect oil-importing countries.

Source: Own processing.

Other studies delved into energy uncertainty and oil market volatility. The research of Alola, Ozkan, & Usman (2023) highlights that energy security has a significant influence on oil prices. Xu, Fu & Lau (2021), and Alola, Ozkan & Usman (2023) found that oil prices are sensitive to energy market movements. Also, Zhang & Guo (2024) proved that energy uncertainty explains the oil price volatility.
Based on the findings presented above, the following research hypotheses were established:
H1: Energy supply in CEE countries is significantly correlated with inflation, oil rents, imports and exports of energy, and general government net deficit.
H2: Final energy consumption in CEE countries is significantly correlated with inflation, oil rents, imports and exports of energy, and general government net deficit.

3. Research Methodology

This study started with the premise that there are several interconnections between the energy sector and oil prices in six CEE countries: Bulgaria, Czech Republic, Hungary, Poland, Romania, and Slovakia. To explore the causal relationship between oil price movements and the energy sector a database composed of the following indicators was constructed (Table 2).

Table 2 Data and variables

Variables	Construction mechanism	Unit/Scale	Sources
Dependent variable			
Total energy supply (EN_SUPPLY)	The overall supply of energy.	Thousand tonnes of oil equivalent	Eurostat database
Final energy consumption (EN_CONS)	The total energy consumed by final users.	Thousand tonnes of oil equivalent	Eurostat database
Independent variables			
Inflation (INF)	The annual percentage change in the consumer price index.	%	World Bank database
Oil rents (OIL_R)	The difference between the value of crude oil production and total costs of production.	% of GDP	World Bank database
Imports of energy (EN_IMP)	Total energy imported.	Thousand tonnes of oil equivalent	Eurostat database

Exports of energy (EN_EXP)	Total energy exported	Thousand tonnes of oil equivalent	Eurostat database
General government net lending (+) /net borrowing (-) (GG_NLNB)	Government surplus or deficit.	% of GDP	Eurostat database

Source: Own processing.

The data was available for the period 2015-2022. The evolution of oil rents as a percentage of GDP reflects a varying trend in all six CEE countries. The higher values were recorded in Romania, even if there was a decrease of 62% in the value of the oil rents since 1995. Hungary also recorded a drop in the value of oil rents of 40%. In Poland and Bulgaria, the value of this indicator increased by 270%, respectively by 33% since 1995 (Figure 1).

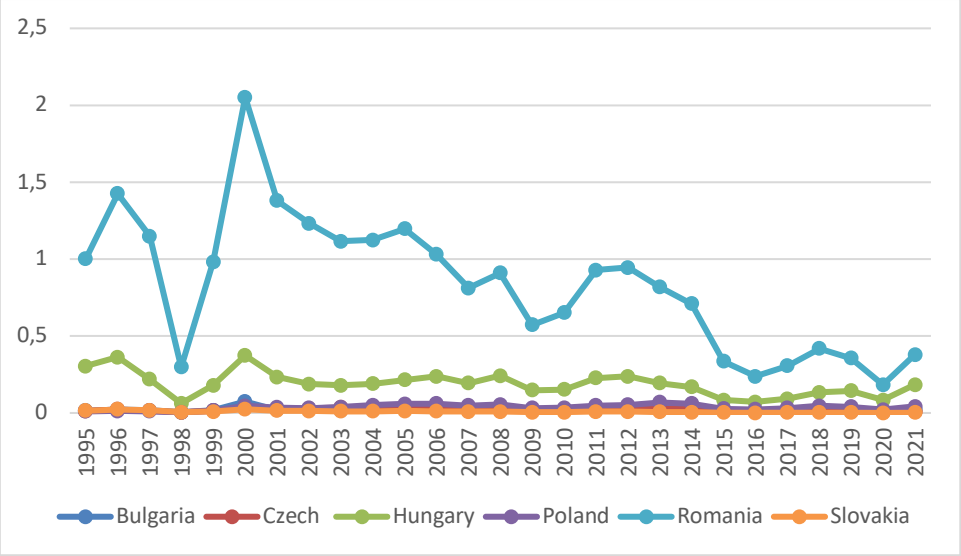

Figure 1 Evolution of oil rents (% of GDP)
Source: Own compilation.

Energy supply exceeded energy consumption in all CEE countries between 1995-2022. The largest energy supply was recorded in Poland, the Czech Republic, and Romania. During this period, in Poland, the energy supply increased by 4%, but in all other CEE countries, this indicator decreased. In Romania, energy supply dropped by 32%, in Bulgaria by 16%, and in Slovakia by 7% (Figure 2).

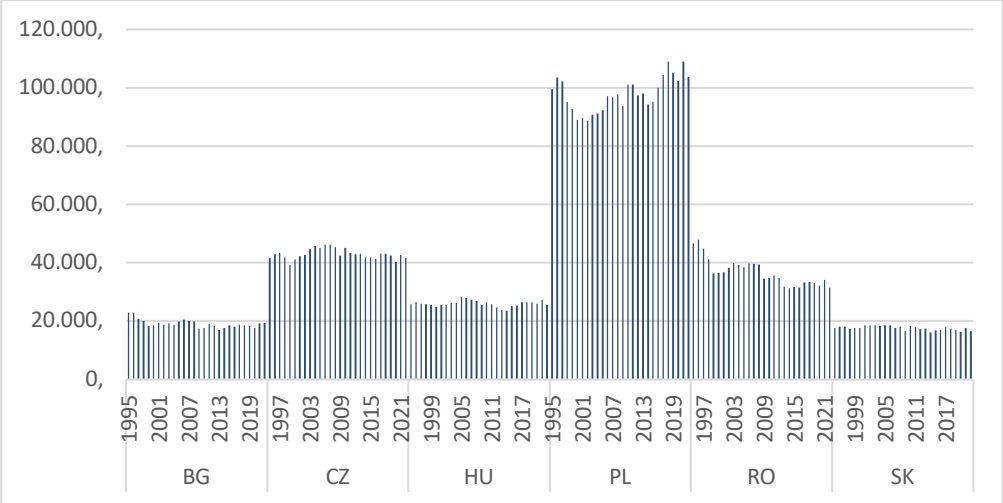

Figure 2 Evolution of energy supply
Source: Own compilation.

Poland, the Czech Republic, and Romania are also the largest consumers of energy in CEE countries. Between 1995 and 2022 energy consumption was reduced in all CEE countries, except Poland and Hungary which recorded an increase of 15%, respectively 13% of final energy consumption (Figure 3).

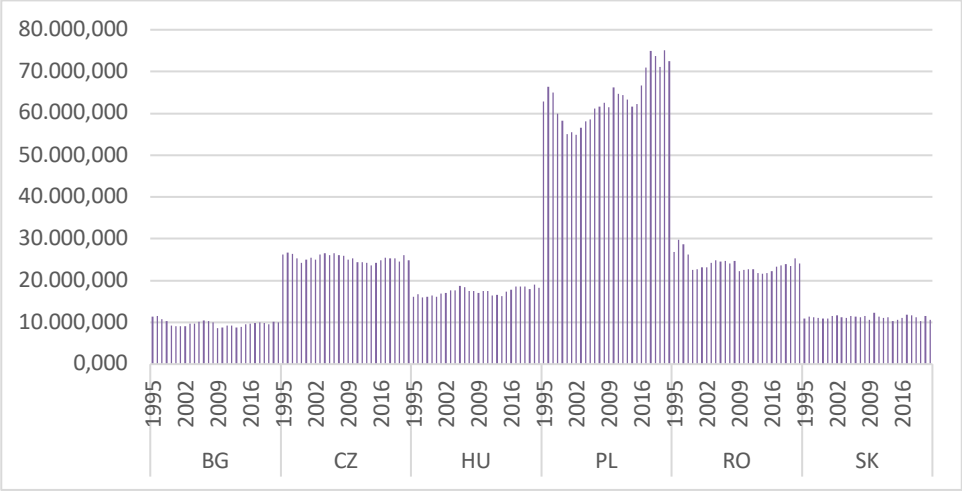

Figure 3 Evolution of energy consumption
Source: Own compilation

The econometric tests for studying the influence of oil price movements on the supply and consumption of energy in CEE countries were performed using the EViews 12 Academic Edition software and Python 3.0 software. The econometric analysis used pool data regression models for period and cross-section statistical analysis of variables. There were used two widespread research methods in economic studies: Ordinary Least Squares (OLS) and Pooled Instrumental Variables (IV) - Two-stage Least Squares (2SLS).

The ordinary Least Squares (OLS) method was applied without effects, with fixed effects, and with random effects and used the following regression equation for estimating the relationship between oil rents, as an independent variable, and energy supply and consumption, as dependent variables:

$$EN\_SUPPLY_{it} = \alpha + \beta_1 \times INF_{it} + \beta_2 \times OIL\_R_{it} + \beta_3 \times EN\_IMP_{it} + \beta_4 \times EN\_EXP_{it} + \beta_5 \times GG\_NLBL_{it} + \varepsilon_{it} \quad (1)$$

$$EN\_SUPPLY_{it} = -8899.100 + 11.8048 \times INF_{it} + 15394.48 \times OIL\_R_{it} + 1.0838 \times EN\_IMP_{it} + 3.0735 \times EN\_EXP_{it} - 217.7210 \times GG\_NLBL_{it} + \varepsilon_{it} \quad (1a)$$

$$EN\_SUPPLY_{it} = 27002.78 - 1.7356 \times INF_{it} + 3362.702 \times OIL\_R_{it} + 0.5255 \times EN\_IMP_{it} + 0.2086 \times EN\_EXP_{it} + 78.84 \times GG\_NLBL_{it} + \varepsilon_{it} \quad (1b)$$

$$EN\_SUPPLY_{it} = -5677.540 + 5.6363 \times INF_{it} + 10704.00 \times OIL\_R_{it} + 1.1125 \times EN\_IMP_{it} + 2.6798 \times EN\_EXP_{it} - 209.7861 \times GG\_NLBL_{it} + \varepsilon_{it} \quad (1c)$$

$$EN\_CONS_{it} = \alpha + \beta_1 \times INF_{it} + \beta_2 \times OIL\_R_{it} + \beta_3 \times EN\_IMP_{it} + \beta_4 \times EN\_EXP_{it} + \beta_5 \times GG\_NLBL_{it} + \varepsilon_{it} \quad (2)$$

$$EN\_CONS_{it} = -8690.667 + 6.1683 \times INF_{it} + 10984.16 \times OIL\_R_{it} + 0.8570 \times EN\_IMP_{it} + 1.7546 \times EN\_EXP_{it} - 295.0758 \times GG\_NLBL_{it} + \varepsilon_{it} \quad (2a)$$

$$EN\_CONS_{it} = 13273.63 - 1.7347 \times INF_{it} + 280.1236 \times OIL\_R_{it} + 0.5157 \times EN\_IMP_{it} + 0.1514 \times EN\_EXP_{it} + 34.4403 \times GG\_NLBL_{it} + \varepsilon_{it} \quad (2b)$$

$$EN\_CONS_{it} = -8118.325 + 5.1086 \times INF_{it} + 9801.633 \times OIL\_R_{it} + 0.8575 \times EN\_IMP_{it} + 1.7040 \times EN\_EXP_{it} - 298.9008 \times GG\_NLBL_{it} + \varepsilon_{it} \quad (2c)$$

Where:

α – free coefficient.

EN_SUPPLY – total energy supply.

EN_CONS – final energy consumption.
INF – inflation.
OIL_R – oil rents.
EN_IMP – imports of energy.
EN_EXP – exports of energy.
GG_NLBL – General government Net lending (+) /net borrowing (-).
ε_{it} – regresion error.

The Pooled Instrumental Variables (IV) - Two-stage Least Squares (2SLS) method eliminates the endogeneity of independent variables using instrumental variables. The method was performed with no effects, with fixed and random effects for a better comparison of empirical results. The regression equations used in the econometric study kept oil rents, as an independent variable, and energy supply and consumption, as dependent variables, and are the following:

$$EN\_SUPPLY_{it} = \alpha + \beta_1 \times INF_{it} + \beta_2 \times OIL\_R_{it} + \beta_3 \times EN\_IMP_{it} + \beta_4 \times EN\_EXP_{it} + \beta_5 \times GG\_NLBL_{it} + \varepsilon_{it} \quad (3)$$

$$EN\_SUPPLY_{it} = -10220.58 + 292.6515 \times INF_{it} + 12940.17 \times OIL\_R_{it} + 1.0662 \times EN\_IMP_{it} + 3.2047 \times EN\_EXP_{it} - 75.75 \times GG\_NLBL_{it} + \varepsilon_{it} \quad (3a)$$

$$EN\_SUPPLY_{it} = 25852.85 + 69.2504 \times INF_{it} + 2343.663 \times OIL\_R_{it} + 0.5555 \times EN\_IMP_{it} + 0.2180 \times EN\_EXP_{it} + 57.5350 \times GG\_NLBL_{it} + \varepsilon_{it} \quad (3b)$$

$$EN\_SUPPLY_{it} = -5351.911 + 192.3169 \times INF_{it} + 6790.319 \times OIL\_R_{it} + 1.0814 \times EN\_IMP_{it} + 2.6538 \times EN\_EXP_{it} - 213.4639 \times GG\_NLBL_{it} + \varepsilon_{it} \quad (3c)$$

$$EN\_CONS_{it} = \alpha + \beta_1 \times INF_{it} + \beta_2 \times OIL\_R_{it} + \beta_3 \times EN\_IMP_{it} + \beta_4 \times EN\_EXP_{it} + \beta_5 \times GG\_NLBL_{it} + \varepsilon_{it} \quad (4)$$

$$EN\_CONS_{it} = -9616.082 + 138.7117 \times INF_{it} + 10323.95 \times OIL\_R_{it} + 0.8610 \times EN\_IMP_{it} + 1.7924 \times EN\_EXP_{it} - 259.8615 \times GG\_NLBL_{it} + \varepsilon_{it} \quad (4a)$$

$$EN\_CONS_{it} = 12770.21 + 10.6334 \times INF_{it} + 137.3716 \times OIL\_R_{it} + 0.5441 \times EN\_IMP_{it} + 0.1159 \times EN\_EXP_{it} + 34.0956 \times GG\_NLBL_{it} + \varepsilon_{it} \quad (4b)$$

$$EN\_CONS_{it} = -5940.261 + 113.6786 \times INF_{it} + 4037.491 \times OIL\_R_{it} + 0.8403 \times EN\_IMP_{it} + 1.4976 \times EN\_EXP_{it} - 307.6685 \times GG\_NLBL_{it} + \varepsilon_{it} \quad (4c)$$

Where:
α – free coefficient.
EN_SUPPLY – total energy supply.
EN_CONS – final energy consumption.
INF – inflation.
OIL_R – oil rents.
EN_IMP – imports of energy.
EN_EXP – exports of energy.
GG_NLBL – General government Net lending (+) /net borrowing (-).
ε_{it} – regresion error.

4. Empirical results

The descriptive statistics presented in Table 3 reflect the large spread in the distribution of the dependent variables, with positive skewness and a leptokurtic kurtosis, leading to a higher probability for extreme values. The descriptive statistics of independent variables show similar results, only government surplus or deficit having a negative skewness.

Table 3 Descriptive statistical analysis

Variable	Obs	Mean	Median	Max	Min	St. Dev.	Skewness	Kurtosis	Jaque-Berra
EN_ SUPPLY	160	40282.09	31441.52	109039.6	16095.66	27675.63	1.3710	3.4940	51.7565
EN_ CONS	160	25346.43	21741.04	75161.98	8591.66	18358.29	1.4339	3.7745	58.8299
INF	160	13.9597	3.7853	1058.37	- 1.5447	84.3888	11.9894	148.5346	145035.4
OIL_ R	160	0.1884	0.0359	2.0519	0.0004	0.3500	2.6342	10.0232	513.8822
EN_ IMP	160	20780.19	17346.11	64155.28	10105.10	11389.21	2.1165	7.0084	226.5804
EN_ EXP	160	7341.000	5103.456	23842.28	1670.560	5551.507	1.5560	4.2363	74.7569
GG_ NLBL	160	-3.5118	-3.5000	2.7000	-12.6000	2.8465	-0.3785	3.3483	4.6309

Source: Own processing using EViews 12 Academic Edition software.

The coefficient covariance matrix of independent variables suggests that there is a relationship between them. It is noted the opposite variation between inflation and oil prices, energy imports, and government surplus/deficit. Oil prices seem to vary in the same direction as imports and exports of energy and the government surplus/deficit. There is an opposite variation between imports of energy and exports and between government surplus/deficit and exports of energy (Table 4).

Table 4 Coefficient covariance matrix

Variable	C	INF	OIL_R	EN_IMP	EN_EXP	GG_NLBL
C	1389040					
INF	-041.4870	29.588				
OIL_R	-578134.1	-12.6588	2036550			
EN_IMP	-36.2716	-0.0095	6.9914	0.0045		
EN_EXP	-0.29551	0.0630	17.9052	-0.0078	0.0216	
GG_NLBL	87100.36	-24.3992	18319.77	0.7565	-0.7522	29375.62

Source: Own processing using EViews 12 Academic Edition software.

The correlation matrix of CEE counties reflects the independence and the regional cohesion. There is a negative correlation between the Czech Republic and Hungary and between Slovakia and Bulgaria, the Czech Republic, Poland, and Romania (Table 5).

Table 5 Residual correlation matrix

Variable	BG	CZ	HU	PL	RO	SK
BG	1.0000					
CZ	0.3096	1.0000				
HU	0.4500	-0.3396	1.0000			
PL	0.3042	0.1298	0.2396	1.0000		
RO	0.1667	0.1848	0.3636	0.2389	1.0000	
SK	-0.0689	-0.8040	0.5489	-0.0198	-0.1138	1.0000

Source: Own processing using EViews 12 Academic Edition software.

The plots are conducted to establish the relationship between dependent and independent variables. Figure 4 presents the plotting results between final energy consumption and macroeconomic variables, exposing the direct and positive correlation between final energy consumption and inflation, GDP, and import and export of energy. The increase in inflation, GDP, and import and export of energy will lead to a larger energy consumption. The plots reflecting the relationship between the final consumption of energy and the government surplus/deficit have a larger spread, suggesting the complex relationship established between these two economic indicators.

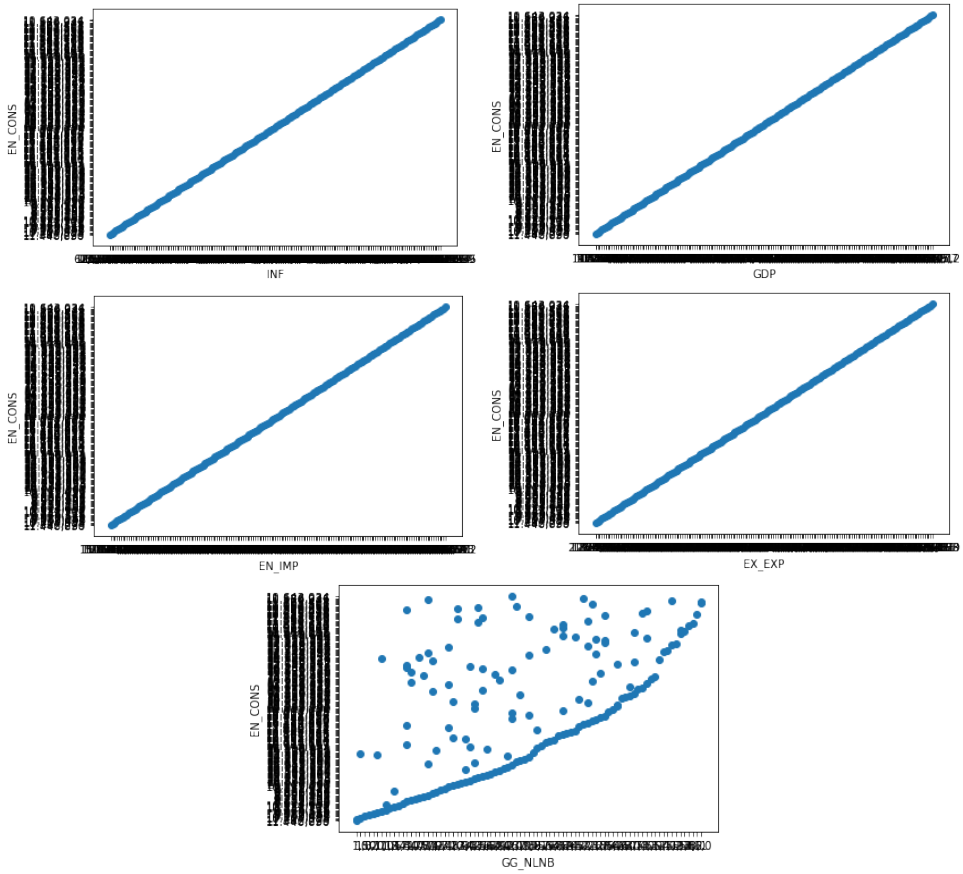

Figure 4 Plots regarding the connections between total final energy consumption and macroeconomic variables
Source: Own processing using Python 3.0 software.

Figure 5 presents the plotting results between energy supply and macroeconomic variables, exposing the direct and positive correlation between energy supply and inflation, GDP, and import and export of energy. The plots reflecting the relationship between the energy supply and the government surplus/deficit have a larger spread, suggesting that the energy supply does not react at the same pace as the general government deficit.

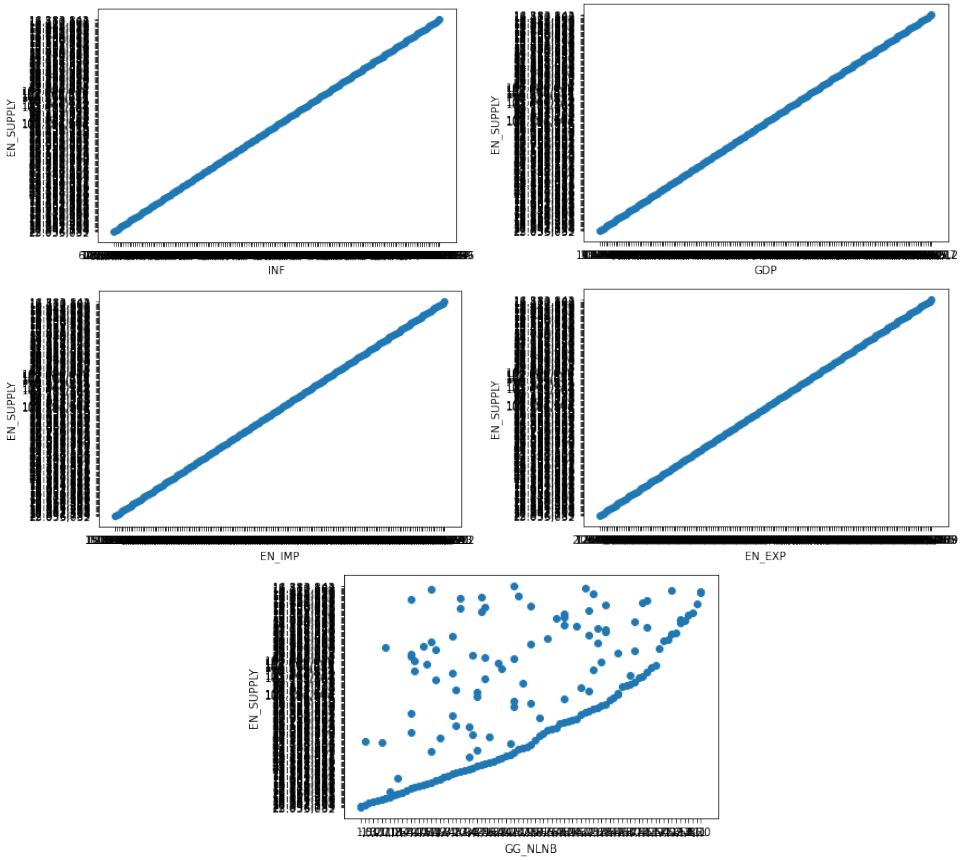

Figure 5 Plots regarding the connections between energy supply and macroeconomic variables

Source: Own processing using Python 3.0 software.

4.1. Empirical results of the OLS method

Table 6 presents the results of the first and second equations tested by the OLS method without effects, with fixed effects, and with random effects. The models used are validated and significant with a value of R-squared over 90%. Both energy supply and energy consumption are positively correlated with oil rents, imports, and exports of energy. Results show that inflation manifests a positive influence on the supply and consumption of energy in the no-effects and random-effects tests but has a negative influence in the case of fixed-effects tests. The government surplus/deficit impacts the supply and consumption of energy negatively in the case of OLS with no effects and random effects analysis, but the OLS with fixed effects display a

positive correlation between them. However, the p values of t-tests reflect that only imports and exports are relevant predictors of the supply and consumption of energy.

Table 6 Ordinary Least Square (OLS) results

	EN_SUPPLY			EN_CONS		
	OLS	FE	RE	OLS	FE	RE
c	-8899.100 (-7.55)	27002.78 (17.00)	-5677.540 (-3.51)	-8690.667 (-11.94)	13273.63 (12.09)	-8118.325 (-9.97)
INF	11.8048 (2.17)	-1.7356 (-0.97)	5.6363 (1.26)	6.1683 (1.83)	-1.7347 (-1.41)	5.1086 (1.59)
OIL_R	15394.48 (10.78)	3362.702 (3.83)	10704.00 (6.50)	10984.16 (12.47)	280.1236 (0.46)	9801.633 (10.32)
EN_IMP	1.0838 (16.09)	0.5255* (13.10)	1.1125 (19.00)	0.8570* (20.62)	0.5157* (18.60)	0.8575* (21.32)
EN_EXP	3.0735 (20.89)	0.2086* (1.67)	2.6798 (18.89)	1.7546 (19.32)	0.1514* (1.75)	1.7040 (18.87)
GG_NLBL	-217.7210 (-1.27)	78.84 (0.96)	-209.7861 (-1.23)	-295.0758 (-2.78)	34.4403 (0.60)	-298.9008 (-2.78)
R-Squared	0.95	0.99	0.90	0.96	0.99	0.95
F / Wald	665.8254	1288.642	277.9453	778.3340	1194.430	583.3615

Notes: *p<0.1; **p<0.05; ***<0.01; t statistics values are presented in parenthesis.
Source: Own processing using EViews 12 Academic Edition software.

4.2. Empirical results of the 2SLS method

Table 7 presents the results of the third and fourth equations tested by the 2SLS method without effects, with fixed effects, and with random effects. The models with no effects and fixed effects are validated and significant with a value of R-squared over 95%, and the models with random effects are partially significant with a value of R-squared over 85%. Both energy supply and energy consumption are positively correlated with inflation, oil rents, imports, and exports of energy. Results show that government surplus/deficit negatively influences the supply and consumption of energy in the case of 2SLS with no effects and random effects analysis, but the 2SLS with fixed effects display a positive correlation between them. However, the p values of t-tests reflect that only imports and exports are relevant predictors of the supply and consumption of energy.

Table 7 Two-Stage Least Square (2SLS) results

	EN_SUPPLY			EN_CONS		
	2SLS	FE	RE	2SLS	FE	RE
c	-10220.58 (-8.37)	25852.85 (15.87)	-5351.911 (-2.61)	-9616.082 (-12.56)	12770.21 (11.37)	-5940.261 (-4.52)
INF	292.6515 (4.01)	69.2504 (2.75)	192.3169 (3.17)	138.7117 (3.03)	10.6334 (0.61)	113.6786 (3.11)
OIL_R	12940.17 (7.46)	2343.663 (2.51)	6790.319 (3.31)	10323.95 (9.49)	137.3716 (0.21)	4037.491 (3.09)
EN_IMP	1.0662 (15.30)	0.5555* (14.68)	1.0814 (18.48)	0.8610* (19.71)	0.5441* (20.87)	0.8403* (22.33)
EN_EXP	3.2047 (20.41)	0.2180* (1.65)	2.6538 (16.31)	1.7924 (18.20)	0.1159* (1.27)	1.4976 (14.17)
GG_NLBL	-75.75 (-0.36)	57.5350 (0.62)	-213.4639 (-1.00)	-259.8615 (-1.98)	34.0956 (0.53)	-307.6685 (-2.40)
R-Squared	0.96	0.99	0.85	0.96	0.99	0.86
F / Wald	930.8297	1637.920	231.5608	1089.240	1511.052	250.9938

Notes: *p<0.1; **p<0.05; ***<0.01; t statistics values are presented in parenthesis.
Source: Own processing using EViews 12 Academic Edition software.

5. Discussion and recommendation

The paper aimed to study the nexus between oil price movements and the energy sector in CEE countries. The geopolitical changes of the XXth century imposed a social and economic transition in CEE countries and a large reforming process to enhance the welfare and sustainable development of economic sectors, including the energy sector. The COVID-19 pandemic and the war between Russia and Ukraine increased the interest in the independence and energy security of European countries. The empirical findings of this study reveal that the supply and final consumption of energy is influenced by inflations, oil rents, imports and exports of energy, and general government deficit, but the most important determining factors are imports and exports of energy. The results align with Wood & Alsayegh (2014) which found that changes in oil prices, GDP, population, and government policies on economic diversification and energy conservation all play a role in determining energy demand.

As in previous studies, this paper enhances the complex relationship between oil prices and the energy sector, suggesting the need for an intensification of policies aiming the macroeconomic stabilization and regional cohesion. To strengthen the energy sector, and respond properly to the oil price movement trends, policies must consider the heterogeneous effect of climate policy uncertainty on the consumption

of renewable energy and a positive effect on oil prices (Zhou et al., 2023). According to Zhang, Huang & Wang (2023), policies should address also the asymmetric relationship between oil prices, economic policy uncertainty, and technological innovation.

At the same time, sustainable economic growth can be achieved only by the sustainable increase of natural resource prices (Phan, 2023), Degiannakis & Filis (2023) show that inflation is a very useful factor in forecasting the oil market trends.

6. Conclusions and policy implication

Oil prices are a significant factor affecting not only the energy sector but also the overall macroeconomic stability and growth prospects of CEE countries. Fluctuations in oil prices can have a substantial impact on the cost of energy production, transportation, and consumption. As a result, changes in oil prices can influence inflation rates, trade balances, fiscal policies, and overall economic growth in the region. Factors such as energy market regulations, energy infrastructure, technological developments, and geopolitical risks play a significant role in shaping the relationship between oil prices and the energy sector.

The empirical research of this paper aimed to expand the research of energy security in CEE countries and to provide some insights regarding the nexus between oil price movements and the energy sector. Our findings show that there is a positive correlation between the energy supply and final consumption, as a dependent variable, and oil rents, imports, and exports of energy, as the independent variable. The results led to the conclusion that the most significant influence on energy supply and consumption is the energy commercial balance.

As political instability and economic uncertainty increase, there is a need to enhance the independence and security of the energy sector. The study suggests that the governments of CEE countries must pay close attention to imports and exports of energy to attain the energy security of their countries. Therefore, the empirical results may be a starting point for consolidating the energy sector in CEE countries.

The study aimed to explore the influence of oil price movements on energy supply and consumption and is limited to six CEE countries. Therefore, the research can be extended to a larger sample of countries to enhance the energy sector context more broadly. At the same time, other empirical methods could be applied to explore the determinants and the correlational factors that influence the energy sector. Also, it will be very useful to consider other explanatory variables for extending research in the field of the energy sector.

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Author Contributions
FCD is the project coordinator and is responsible for teamwork. ȘAN and SN have constructed the empirical database and are responsible for the empirical results analysis and interpretations. FCD has been in charge of econometric modeling techniques and software computation and results computation. ȘAN, SN, CB, and LP are responsible for the literature review section. Discussion and recommendations are computed by ȘAN and SN. The conclusions section is constructed and agreed upon by all authors. CB is responsible for the English supervision of the manuscript. All authors have provided inputs for the manuscript's content and editing.

Disclosure statement
The authors do not have any competing financial, professional, or personal interests from other parties.

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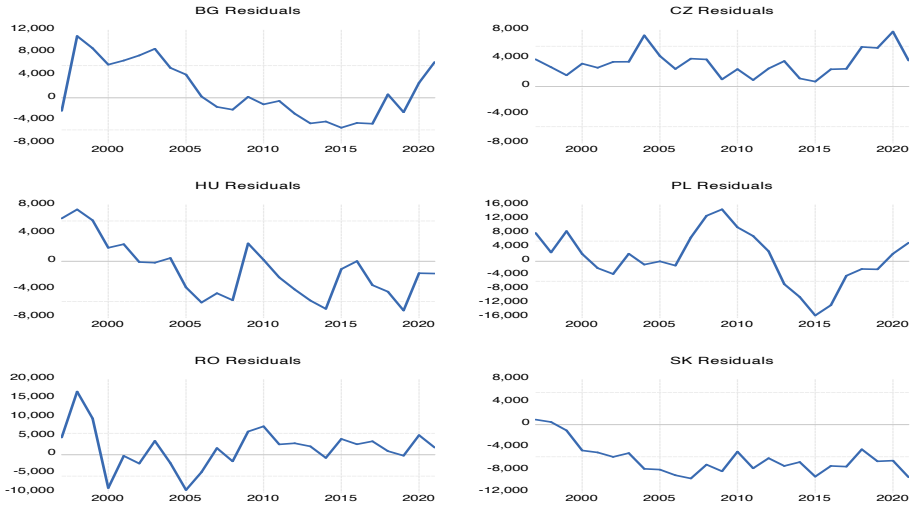
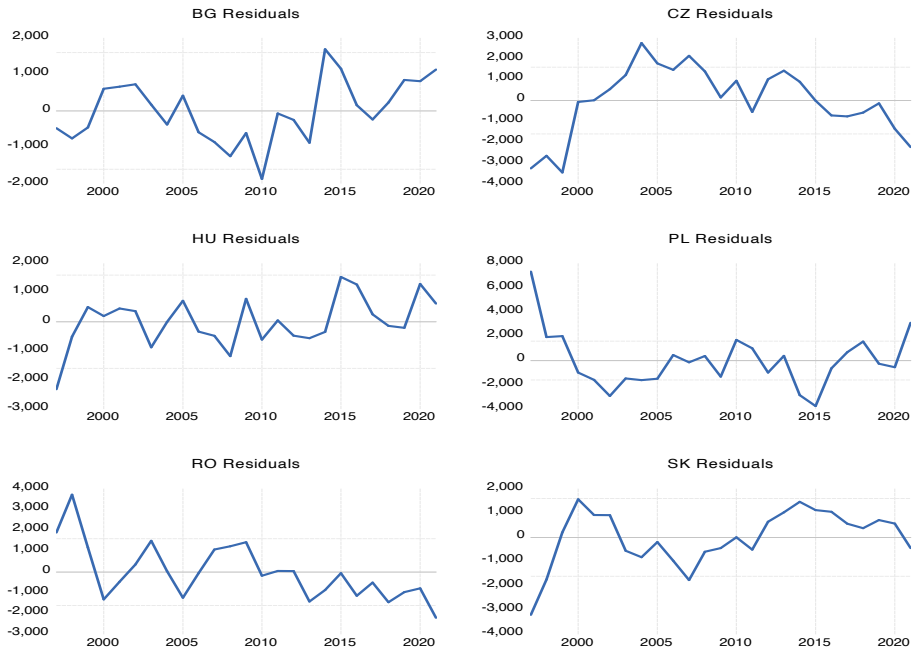
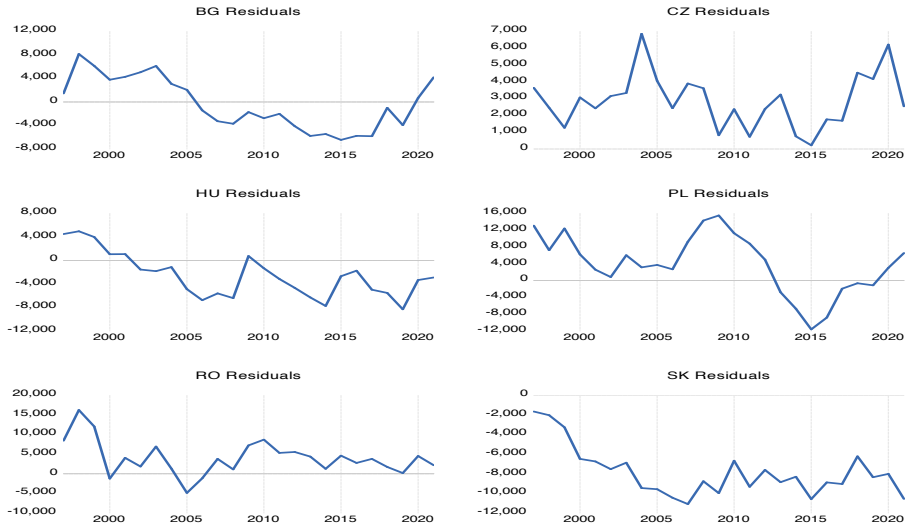
Appendix 1a Residuals – OLS – EN_SUPPLY dependent variable



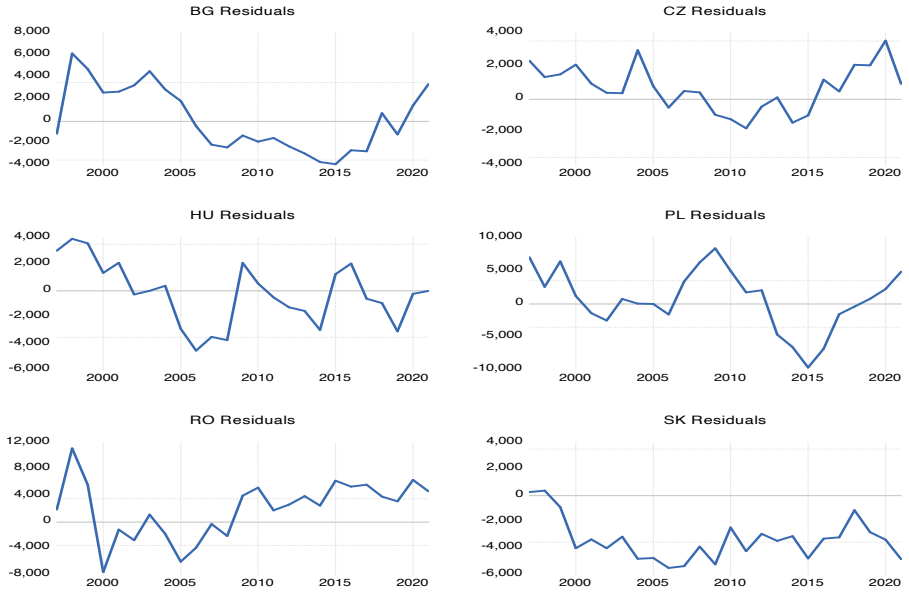
Appendix 1b Residuals – OLS – Fixed effects – EN_SUPPLY dependent variable



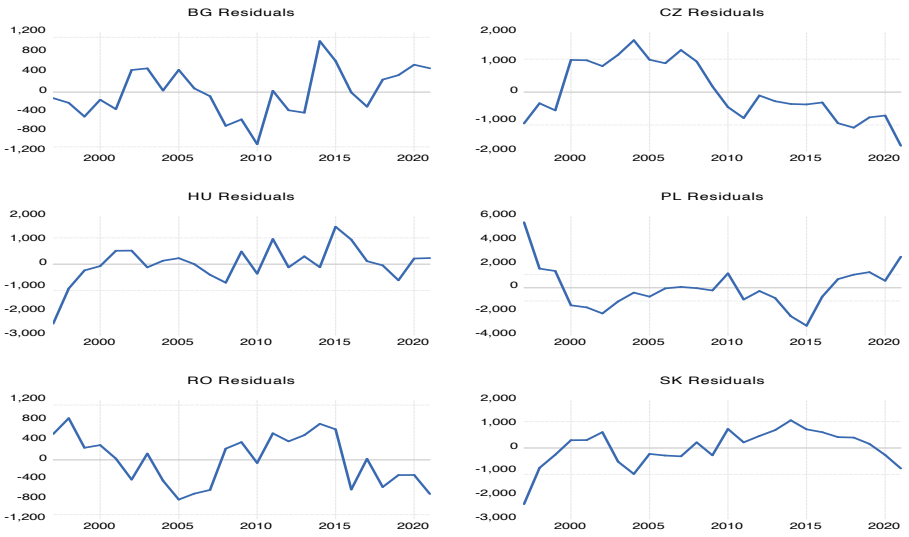
Appendix 1c Residuals – OLS – Random effects – EN_SUPPLY dependent variable



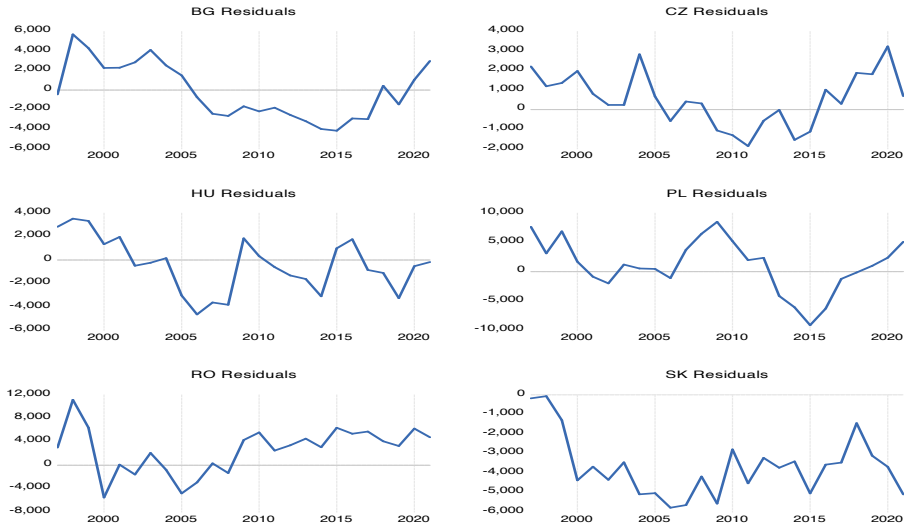
Appendix 2a Residuals – OLS – EN_CONS dependent variable



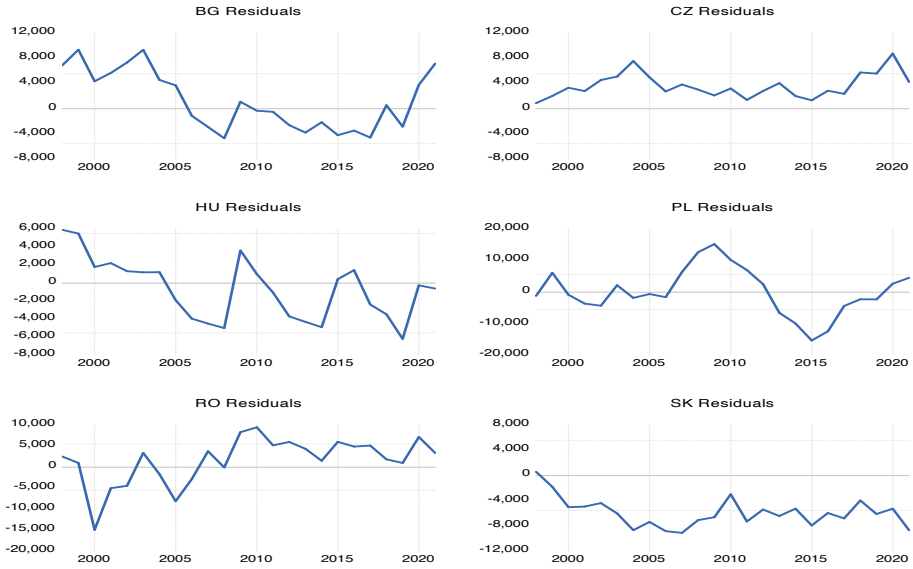
Appendix 2b Residuals – OLS – Fixed effects – EN_ CONS dependent variable



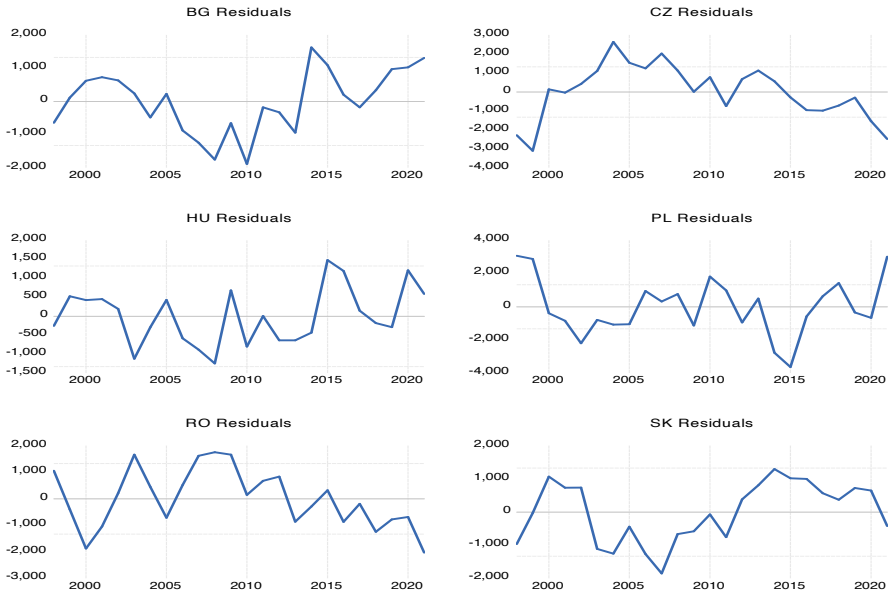
Appendix 3a Residuals – OLS – Random effects – EN_ CONS dependent variable



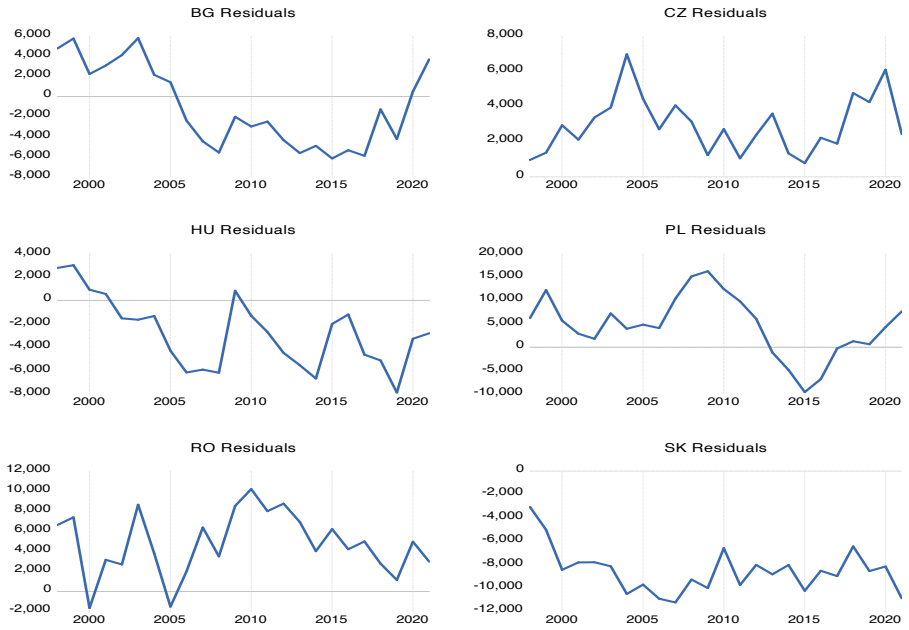
Appendix 3b Residuals – 2SLS – EN_SUPPLY dependent variable



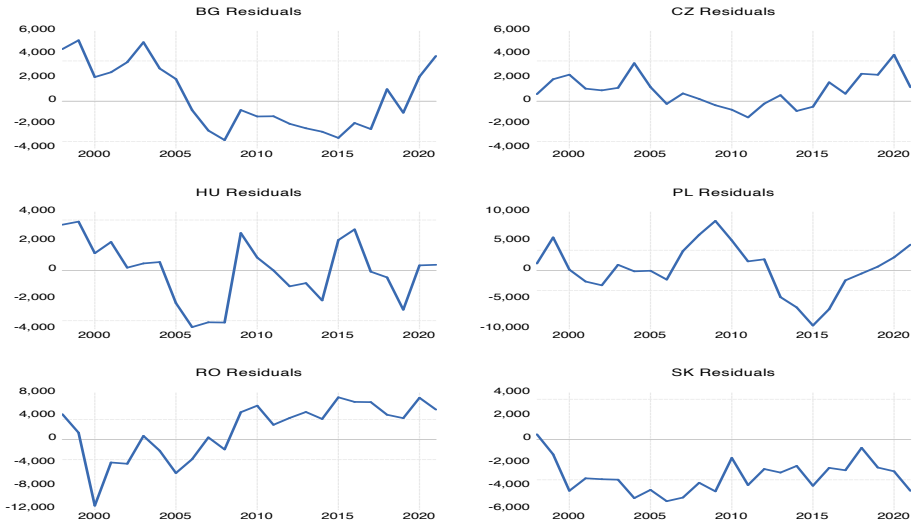
Appendix 3c Residuals – 2SLS – Fixed effects – EN_SUPPLY dependent variable



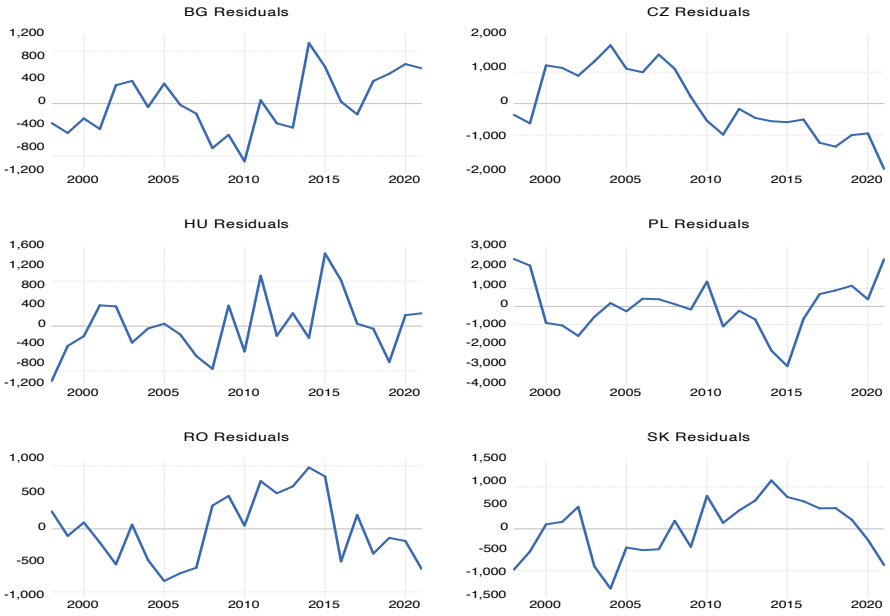
Appendix 3d Residuals – 2SLS – Random effects – EN_SUPPLY dependent variable



Appendix 4a Residuals – 2SLS – EN_CONS dependent variable



Appendix 4b Residuals – 2SLS – Fixed effects – EN_CONS dependent variable



Appendix 4c Residuals – 2SLS – Random effects – EN_CONS dependent variable