energies

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Climate Change, Exchange Rate, Twin Deficit, and Energy Inflation: Application of VAR Model

Shazia Kousar [1], Saeed Ahmad Sabir [2], Farhan Ahmed [3] and Štefan Bojnec [4,*]

1 Department of Economics, Lahore College for Women University, Lahore 54000, Pakistan
2 Hailey College of Commerce, University of the Punjab, Lahore 54000, Pakistan
3 Department of Economics and Management Sciences, NED University of Engineering and Technology, Karachi 75270, Pakistan
4 Faculty of Management, University of Primorska, SI-6101 Koper-Capodistria, Slovenia
* Correspondence: stefan.bojnec@fm-kp.si or stefan.bojnec@siol.net

Abstract: The motivation behind the study is continuous fluctuations in energy prices in Pakistan, so this study aims to investigate the role of a twin deficit, urbanization, climate change, energy production from oil and gas, and the exchange rate in energy inflation. This study utilized oil prices and electricity prices to capture energy inflation using time series data from 1972 to 2021, from World Development Indicators (WDI) and the Census of Electricity Establishment (CEE). This study utilized the vector auto-regressive (VAR) model to investigate the short-run and long-run estimates. This study found that the twin deficit and the exchange rate have a significant and positive association with energy inflation. However, the size impact of the twin deficit is greater on oil prices as compared to electricity prices. Furthermore, urbanization, climate change, and energy production from oil and gas have a positive and significant long-run association with electricity prices. Moreover, the results of the variance decomposition test indicate that the relative contribution of the budget deficit in electricity prices (Model 1) is greater than other modeled variables, while the relative contribution of the budget deficit and climate change is greater in oil prices (Model 2), as compared to other exogenous variables. This study helps policymakers to devise policies to control energy inflation, which affects the well-being of society.

Keywords: climate change; urbanization; twin deficit; energy prices; Vector Auto-Regressive Model; electricity prices; oil prices

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Citation: Kousar, S.; Sabir, S.A.; Ahmed, F.; Bojnec, Š. Climate Change, Exchange Rate, Twin Deficit, and Energy Inflation: Application of VAR Model. *Energies* **2022**, *15*, 7663. https://doi.org/10.3390/en15207663

Academic Editor: Behnam Zakeri

Received: 3 August 2022
Accepted: 12 October 2022
Published: 17 October 2022

1. Introduction

Energy is considered a key driver for sustainable socioeconomic progress. Among numerous indicators of measuring living standards, one indicator of key importance is energy consumption. In the wake of technological development and industrial growth, consumption of energy is rapidly enhancing globally in general and particularly in developing countries of Asia [1–3]. The projection made by the International Energy Agency (IEA, 2019) indicates that the energy demand will increase by 25% globally and around 40% in the Asian economies by 2040. In total, Asia will contribute 50% growth in the demand for natural gas, 80% to crude oil, and almost 100% to coal. Accordingly, Asia will contribute to a two-third increase in demand for energy consumption overall, which is very alarming (IEA, 2019).

Similar to other developing economies, Pakistan is also facing a potential energy consumption imbalance for many years to come [2]. Many less favorable socioeconomic implications are expected to arise in the context. However, fewer academic studies and policy initiatives are witnessed to deal with the severity of the issue. In the last one and half decades, energy consumption increased by about 80% but energy production did not increase accordingly. Hence, the demand-supply gap is prominent and increasing day after day [4,5].

In addition, the United States (US) Energy Information Agency empirically represents the positive association of energy supply in attaining sustainable financial growth in the context of developing as well as developed countries (EIA 2018). Pakistan is a developing country with over 200 million population that is still rapidly increasing and resulting in a high energy demand [6]. Both household and manufacturing users are contributing to the increasing demand for energy. The economy of the country is dominated by the manufacturing industry. For this reason, the energy shortage is resulting in dire consequences for the whole economy.

Accordingly, the electricity sector of Pakistan requires privileged attention from policy-making authorities to achieve sustainable and long-term growth. In the literature, numerous studies highlight the significance of electricity as a lifeline for the economy of Pakistan [2,7–11]. Electricity is a form of energy and all production processes of the manufacturing industry are based on energy. In the last two decades, the poor performance of the industry in Pakistan has its roots in energy failure [12]. By 1980, the total energy usage of Pakistan was around 24.8 million metric tons and the output of energy was 20.8 million metric tons. The demand for energy was 13,206 MW in 2005, which increased to 18,827 MW in 2013, however, the production of energy was almost the same in this period. In 2017, the shortfall of electricity was 8000 MW, which increased to 13,000 MW. The demand and supply gap of energy not only remained or was continuous but also increased, ultimately affecting the prices of energy [13].

This research examines the effect of climate change, the exchange rate, and a twin deficit on energy inflation in the context of Pakistan. Energy inflation is measured through electricity prices and oil prices. The twin deficit includes a budget deficit and trade deficit. In the literature, many studies have analyzed energy inflation in the context of different economies with different periods by incorporating various research techniques and parameters. Variables addressed in the previous studies include urbanization, energy consumption, gross domestic product (GDP), and environmental hazards [2,6,10]. However, this study attempts to contribute to the existing literature in multiple ways. First, this study used a unique nexus of variables such as climate change, the exchange rate, and a twin deficit to address the prevailing gap for suitable policy initiatives. Potentially, this approach seems more comprehensive to study the causes of energy inflation in Pakistan. Second, the sample from Pakistan is the population of this study due to its significant relevance to the topic concerning energy inflation as well as climate change, the exchange rate, and a twin deficit. The energy sector of Pakistan has been facing several issues regarding the prices of energy for the last few years [2]. Pakistan's energy sector is mostly dependent on imported furnaces oil, which is very expensive internationally. Moreover, low usage of local resources like coal and hydrological power in the production of energy leads to energy shortages and hikes in the energy prices [2,6]. Third, most studies concluded that the usage of energy is a cause of environmental degradation [2,14,15], while this study contributes to the literature by investigating the impact of climate change on energy inflation. Finally, this study utilized the vector auto-regressive (VAR) model to investigate the short-run and long-run effects of climate change, the exchange rate, and a twin deficit on energy inflation.

The rest of this paper is organized as follows. The Section 2 entails a review of the existing literature. The Section 3 presents the material and methods. The Section 4 consists of results and discussion and the Section 5 contains the conclusion and policy suggestions.

2. Literature Review

Pakistan is facing the worst crisis in energy [2,16]. Mahmood, Razzaq [17] claimed that significant factors behind energy crises include poor policies regarding energy, political instability in the country, and the weak grip of the state on the law-and-order situation. Alike, Komal, and Abbas [18] concluded that over-dependency on fossil fuels (around 80%), unstable financial positions of energy supply companies, heavy circular debts, depleting reserves of gas and improper application of cheap energy production sources (hydel and coal) are leading causes of energy crises in the country. In Pakistan, the average per capita consumption of electricity is about 456 kilowatt hours (KWh), which is 30% less compared to other Asian countries and 25% less than global per capita consumption [2]. Mahmood, Razzaq [17] highlighted that the shortfall of electricity was 8000 MW in 2017, which increased by 13,000 MW by 2020 [16]. The World Energy Outlook concluded that about 27% of the total population of Pakistan does not have access to electricity, while the remaining major part of the population does not have a reliable electricity connection. Pakistan is a developing country with different features of development and transmission of technologies as compared to developed countries. Furthermore, Pakistan has an abundance of natural resources that potentially can produce electricity at lower prices. Among these natural resources, solar, hydropower, coal, and wind are significant [19,20]. However, Pakistan is not fully using these resources to produce energy and depends on imported energy sources. Increasing the energy demand forced us to import more and more energy to fulfill the requirements. If the country failed to import energy, there would be dire consequences for the economy because energy consumption has a direct link with the economic development of a country [15,21]. Moreover, energy consumption is also directly associated with industrialization, urbanization, financial growth [22], technological advancement, and social development [17]. Energy supply and consumption in a country largely determines economic development [23]. Accordingly, Ahmed, Mahmood [24] claimed that per capita consumption of energy has a positive impact on financial growth in Pakistan. However, Pakistan is facing a shortage of energy from local resources and the import bill of energy is expected to increase by 30 to 70% by 2025/2026 [25]. In 2014, the Government of Pakistan spent USD 14.5 billion on the import of oil [26]. These imbalances in energy imports, if unaddressed, would result in an alarming decline in gross domestic product (GDP) growth, which was 2.4% in 2019/2020 [27]. In contrast, the foreign exchange rate of the Pakistani rupee (PKR) to the US dollar (PKR/USD) remained negatively unstable in previous years. The rate of PKR/USD fluctuated from 58 to 227 from 2000 until July 2022 with a high rate of devaluation. Despite the highly unstable PKR/USD exchange rate and fluctuating prices of energy in the international market, the energy imports of Pakistan enhanced by 34%, only in the month of July, 2019 [28]. This increased amount is equal to 25% of the total import of the time. In another way, the amount of energy imports is near 60% of total exports, which ultimately affects the electricity prices in Pakistan. In the presence of fewer alternative resources to produce electricity and poor economic performance, numerous serious measures are needed to increase the capacity to produce electricity and to deal with the electricity demand and supply gap. The prices of electricity will increase if the country remains dependent on imports of raw materials to produce electricity instead of producing electricity with alternative sources due to foreign exchange instability.

The main source of electricity production in Pakistan is fossil fuels, which are associated with high costs [29]. Change in electricity expenses results in higher circular debt, and higher subsidies are given to the thermal plants that operate on oil. In addition, managerial flaws, exploitation of resources, corruption, and low budgets create major problems while generating power [30]. Moreover, an increase in electricity prices negatively impacts the quality of life of household users and increases costs and reduces competitiveness for industrial users. To stabilize electricity prices, emergency measures are needed. Despite the instant need for corrective measures for electricity prices in Pakistan, recent literature on the topic is still inadequate and provides an incomplete conclusion.

Numerous studies in the literature focus on the needs and requirements of the electricity sector in Pakistan [2,31]. However, there are hardly any studies that cover the relationship between the exchange rate, twin deficit, climate change, and energy inflation, especially in the context of Pakistan.

2.1. Climate Change and Energy Inflation

Climate change and policies regarding climate potentially affect inflation and monetary policy [32–34]. Pricing or new taxes on market-based carbon emissions can result in higher inflation, particularly regarding fossil fuels [35,36]. However, this inflationary pressure can be reduced by focusing more on innovative methods of renewable energy that ultimately will produce cheap electricity by enhancing energy efficiency. Moreover, it will diminish the energy weight in the consumer price index (CPI) consumption bracket [35,37]. Shifting consumer preferences from carbon pricing towards eco-friendly products and services may also result in a low inflation rate as it is included in the CPI consumption bracket on updating consumer basket weights [38]. In a nutshell, climate change positively impacts the usage of electricity usage, which may increase the price of electricity.

2.2. Exchange Rate and Energy Inflation

The relation between the currency exchange rate and the electricity inflation rate can be comprehended with the help of the purchasing power parity theory presented by Fisher [39]. By studying literature extensively, the exchange rate is considered an important factor for the determination of both short-run and long-run macroeconomic objectives concerning development and growth [40–42] in the context of Nigeria and South Africa; stickier prices were observed in South Africa as compared to Nigeria in the research that examined the influence of exchange rate variation on inflation in both countries. In addition, Yaron, Mangani [43] studied how real effective exchange rates have an impact on GDP in the context of Malawi and concluded a significant negative association among these. Concerning Zimbabwe, Mahonye and Zengeni [44] in their research studied the impact of exchange rate fluctuations on inflation and their associated consequences regarding economic development. They further found that a decrease in the real exchange rate may result in inflation in the country and the phenomenon will potentially enhance exports that ultimately result in a better economic performance of the country. This conclusion about the association of devaluation of the exchange rate and GDP is not clear. Besides this, Roger, Smith [45] examined the relationship between GDP, the exchange rate process, and the prices of copper in Zambia and determined that decrease in inflation was a good factor in exchange rate fluctuations.

Studies associated with exchange rate volatility and trade flows are categorized into two groups of researchers. The first group studied trade transactions of Pakistan with the entire world [46,47]. However, other groups investigate the bilateral and aggregate trade flows of the country with particular major trading counterparts [48,49]. Among these studies, most of them found mixed results by incorporating aggregate trade flows. The aggregation of data cancels the opposite impact of numerous commodities. For this reason, findings from the aggregated data are not appropriate for deciding exchange rates and the formulation of policies for trade about specific commodities or industries. Conclusively, aggregation bias can result in irrelevant discussions and ambiguous policy recommendations. At a later stage, researchers realized that there were deficiencies in aggregate data and attempted to investigate disaggregate data and most still had mixed findings.

The potential analytical flaw is the most important because of the supposition of the exchange rate volatility's symmetric impact on trade flows in the literature. The symmetric effect asserts that by increasing one unit in exchange rate volatility, x percent of trade is increased and vice versa in the case of a reduction in foreign exchange volatility. However, traders in practice may act asymmetrically in response to their trading behaviors or expectations. Illustratively, a businessman who has the intention to trade less while increasing volatility may also trade less in decreased volatility. Loss of market trust, unavailability, or a risk-bearing attitude of financial managers leads to this kind of attitude. Global studies have already reported that not only prices of local commodities [50] but also exports and imports prices [51] react asymmetrically to fluctuations in the exchange rate. Moreover, this asymmetric impact regarding the fluctuations in the exchange rate was found partially not only in the short run but also in long run [52]. Bahmani-Oskooee and Aftab [53] in their study on bilateral industrial trades of Pakistan with Japan distinguished industries that perceive a positive impact of the PKR fluctuations from those that were negatively influenced. Most of the studies focused on the impact of exchange rate variations on overall trade flows, however, the specific impact of exchange on energy inflation is overlooked.

2.3. Twin Deficit and Energy Inflation

Boileau and Normandin [54] concluded in the economics literature that revenues and spending of government are inversely associated. It is believed that a decrease in government revenues will lead to an increase in public spending. This assumption is based on the fact that by lowering taxes, the perception of the public increases that the government has also reduced budgeted programs. Accordingly, there will be pressure on the government to start new programs for the public in response to public demand [55]. When government initiates new programs to respond public demand, expenditure by the government is expected to increase. Hence, the government has to face the issue of fiscal deficit and deficit financing. In addition, according to the displacement effect of Peacock and Wiseman, governments have to spend more in times of instability [56]. This instability or uncertainty may be because of an economic recession where the government is required to spend more to rescue the economy from a major disaster. Peacock and Wiseman's assumption further explains that public expenditure is increased in various steps such as a fashion adopted in times of instability remaining in times of recovery. Furthermore, expenditure made by the government as an attempt to save the economy from major disasters tends to become a permanent trend of public expenditure [57]. On the other hand, this increase in public expenditure may also enhance public revenues by increasing taxes.

Conversely, in the context of Pakistan, the situation is very different because people who pay taxes are often receptive to paying more taxes. Furthermore, inherent challenges in the structure of tax administration that include high tax evasion, inequality in income and wealth, demographic pressures, and inefficiency within the government are some of the major elements that lead to deficit financing at a time of uncertain oil revenues. Moreover, in their political party interests, political governments do not significantly attempt to diversify the tax base to enhance revenue. People mistrust the government regarding the effective use of tax revenues collected from them in creating employment and investing in capital formation. Further, El Anshasy and Bradley [58] found a strong positive association between oil price instability and government expenditures in 16 oil-exporting economies. Adedokun [59] applied the structural vector auto-regressive (SVAR) model to conclude that oil price uncertainty does not considerably predict changes in public expenditure in the short term but in the long run. However, the predictive ability of oil revenue instability was clear and significant both in the long term and short term.

Similarly, Eregha, Aworinde [60] studied the dynamic association between fiscal deficits and current account deficits in response to fluctuating prices of oil in selected countries of Africa that produce oil by incorporating data from the period 1981–2018. The twin deficit hypothesis was proved by the results of the study in the context of African oil-producing economies. The results of the study highlighted that positive oil price fluctuations should not be considered permanent for consumption and the application of effective fiscal policy and structure for controlling crude oil prices in the long run. By applying the ordinary least square (OLS) model, Monjazeb, Choghayi [61] determined that oil revenues are negatively associated with the budget deficit in the settings of countries that export oil.

3. Material and Methods

When the goal of a study is to evaluate a set of equations, vector auto regression (VAR) or vector error correction models (VECM) are suitable approaches. Structural VAR, also known as the VECM, takes into account both immediate and delayed linkages between variables of interest to provide more reliable multivariable time series analysis results. Furthermore, the SVAR/VECM allows the analyst to compute variance decomposition and conduct an impulse response function, which is a specification of how much of the prediction residual variance of each of the parameters can be described by uncontrollable factors towards the other factors [62]. The sequence of integration and the existence of long-run equilibration among a set of time series are the final factors for choosing between VAR and the VECM.

The VECM is a multidimensional time series model that makes it easy to express vector processes with unit root variables and long-run stochastic trends. VECM is appropriate for predicting, causality analysis, and impulse response evaluation [63].

The VECM is used to get the answer to the following research questions:

1. What type of relationship exists between budget deficit (BD) and energy inflation?
2. What type of relationship exists between trade deficit (NX) and energy inflation?
3. What type of relationship exists between exchange rate (ER) and energy inflation?
4. What type of relationship exists between climate change and energy inflation?
5. What type of relationship exists between energy produced from oil and gas (EPOG) and energy inflation?

3.1. Data and Variable Description

This study utilized annual time series data for the period of 1972–2019, from World Development Indicators (WDI) and the Census of Electricity Establishment (CEE). This study utilized six independent variables, including the budget deficit (BD), the trade deficit (NX), the exchange rate (ER), and climate change (CO_2). Moreover, the study utilized two measurements, oil price (OP) and electricity prices (EP), to measure energy inflation. This study utilized urbanization (URBAN) and energy produced from oil and gas (EPOG) as control variables. This study excluded 2019 and 2020 from the study period due to the non-availability of data. Moreover, this study converts annual data into quarterly data using E.Views (S&P Global, New York, NY, USA), specified via the frequency range method for VAR model estimation purposes. The detailed variable description, definition, and data sources are provided in Table 1.

Table 1. Variables, description, measurement and data sources.

Nature of Variable	Notation	Variable Description	Measurement	Data Sources
DV	EP	Electricity price	"End use and average retail prices"	CEE
	OP	Oil prices	"Oil rents (% of GDP)"	WDI
IV	BD	Budget deficit	"Expense (% of GDP)-tax revenue (% of GDP)"	WDI
	NX	Trade deficit	"Exports of goods and services (% of GDP)-imports of goods and services (% of GDP)"	WDI
	ER	Exchange rate	"Official exchange rate (LCU per USD, period average)"; local currency unit (LCU) = Pakistani rupee (PKR)	WDI
	CO_2	Climate change	"CO2 emissions (metric tons per capita)"	CEE
CV	EPOG	The energy produced from oil and gas	"Electricity production from oil, gas, and coal sources (% of total)"	WDI
	URBAN	Urbanization	"Urban population growth (annual %)"	WDI

Note: DV stands for dependent variables, IV stands for independent variables, and CV stands for control variables.

3.2. Model Specification

The vector error correction model (VECM) is used to investigate the short-run and long-run relationships among the modeled variables.

The error correction term (ECT) equation is defined as follows:

$$\Delta y_t = \propto \varepsilon_{t-1} + \gamma\, \Delta x_t + \mu_t$$

where $\propto$ explains the co-integrating coefficient and ε represents the error term from the regression of y_t on x_t, and the VECM equation is described as follows:

$$\Delta y = \delta + \beta_0 \Delta X_t - \Pi \cup_{t-1} + \in_t$$

where β_0 is the impact size of independent variables on the dependent variable in the short run. Π symbol presents the ECT, which explains how much time it will take to adjust back to equilibrium in the case of an external shock that causes the model to diverge from equilibrium. The VECM is the extended form of using the single equation of ECM in a multivariate system [63]. A general autoregressive process helps to find the VAR model in vector form. The VAR model with lag order p is described as follows:

$$y_t = c + A_i y_{t-1} + A_2\, y_{t-2} + \ldots + A_p\, y_{t-p} + e_i$$

where c represents a vector of constants, coefficient matrices signify A_i for lagged values, and e_i symbolizes a vector of error terms.

3.3. Econometric Model

Energy inflation is the dependent variable; thus, to measure energy inflation, this study utilized two measurements, namely, electricity prices and oil prices. Furthermore, six independent variables, namely, budget deficit, trade deficit, urbanization, exchange rate, climate change, and energy produced from oil and gas.

General model:

$$\text{EP} = \infty_1 + \beta_1 BD + \beta_2\,\text{NX} + \beta_3\,\text{URBAN} + \beta_4 ER + \beta_5\, CO_2 + \beta_6 EPOG + \mu \text{ (Model 1)}$$
$$\text{OP} = \infty_1 + \beta_1 BD + \beta_2\,\text{NX} + \beta_3\,\text{URBAN} + \beta_4 ER + \beta_5\, CO_2 + \beta_6 EPOG + \mu \text{ (Model 2)}$$

In Model 1, EP indicates electricity prices for energy inflation, BD is used for the budget deficit, URBAN is used for urbanization, ER indicates the exchange rate, CO_2 is used for climate change, and EPOG is used for energy produced from oil and gas, while in Model 2, OP is used for oil prices and on the right-hand side the variables are the same as in Model 1.

The specific econometric equations for Model 1and Model 2 are reported in the appendix (see Appendix A.1. specific econometric models). These multiple econometric models indicate that all independent variables also become endogenous variables in VAR modeling (see Appendix A.2. system of VAR models).

4. Results and Discussion

Tables 2 and 3 provide descriptive statistics and correlation among all variables. The probability value of Jarque-Bera for all variables is greater than 0.05 or 5%, indicating that the normality assumption is satisfied. The mean, median, and mode are examples of the central tendency of the series, while standard deviation is a measure of the spread of the data, and skewness and kurtosis are examples of the Gaussian distribution of the data. The value of kurtosis indicates that the data are positively skewed while all other series are positively skewed. Similarly, values of kurtosis for all series are less than 3, so the data follows a Gaussian distribution. Moreover, the results of correlation in Table 3 indicate the correlation values among all the independent variables that this study can utilize for further analysis.

Table 2. Descriptive statistics of variables.

	EP	**OP**	**BD**	**NX**	**URBAN**	**ER**	**CO_2**	**EPOG**
Mean	8.754	0.547	−6.662	−5.614	3.563	39.828	0.616	56.061
Median	8.700	0.509	−6.573	−5.966	3.623	29.337	0.632	57.387
Maximum	11.000	1.312	−1.131	0.940	4.505	102.769	0.872	71.826
Minimum	6.900	0.018	−11.563	−12.038	2.665	8.681	0.400	37.996
Std. Dev.	1.085	0.294	2.932	3.619	0.601	30.182	0.142	10.382
Skewness	0.189	0.389	0.178	0.110	−0.126	0.705	0.077	−0.215
Kurtosis	2.337	2.739	2.204	1.996	1.603	2.233	1.637	1.572
Jarque-Bera	1.067	1.237	1.392	1.937	3.694	4.728	3.448	4.077
Probability	0.587	0.539	0.499	0.380	0.158	0.094	0.178	0.130

Table 3. Correlation coefficients between variables.

	BD	NX	URBAN	CO_2	ER1	EPOG
BD	1					
NX	0.129	1				
URBAN	−0.349	−0.377	1			
CO_2	0.194	0.223	−0.732	1		
ER	0.388	0.193	−0.546	0.5106	1	
EPOG	0.201	0.521	−0.881	0.4777	0.799	1

4.1. Unit Root Test

To avoid a spurious relationship, this study utilized a unit root test to check the stationarity of the data. The stationarity of the data demands that the mean, variance, and covariance of the modeled series remain constant across time. Stationarity can be described mathematically, but for our purposes, it refers to a series that seems smooth, has no trend, has equal variances over time, has a consistent covariance structure across time, and has no periodic oscillations. Because non-stationary time series data can generate misleading results, this study employed the unit root test in the first stage of the study to ensure the stationarity of the series.

The stationarity of the data was checked by applying the augmented Dickey-Fuller (ADF) unit root test. The estimated outcomes of the ADF unit root test are presented in Table 4. The results suggest that all variables are integrated at I(1). Thus, in the next step, the study examined the long-run co-integration among the series.

Table 4. Unit root analysis.

Variables	ADF with Intercept		ADF with Intercept and Trend	
	At Level	1st Difference	At Level	1st Difference
EP	−2.029073	−4.075332 *	−1.987178	−4.073957 *
BD	−2.535651	−8.632561 *	−3.059690	−8.844757 *
NX	−2.278699	−7.073476 *	−2.257609	−7.012306 *
CO_2	4.072830	−4.511049 *	−0.603882	−6.087876 *
URBAN	−0.935097	−4.161108 *	−2.389254	−3.927409 *
ER	3.306338	−4.899349	0.717885	−6.291883
EPOG	−1.102821	−9.753611 *	−2.319349	−9.637102 *

Note: * indicates significance at a level of less than 0.05.

4.2. Co-Integration Test

The long-run relationship or co-integration of the series was investigated by utilizing the Johansen co-integration test with the null hypothesis no co-integration exists. The results of the Johansen co-integration test are reported in Table 5. The results of trace statistics and maximum Eigen statistics show that three co-integrating equations exist in the VAR system in Model 1 and 2. Moreover, trace statistics and maximum Eigen statistics indicate that three co-integrating equations exist in Model 1 and 2. Therefore, a long-run co-integration exists among the modeled equations. After confirmation of long-run co-integration, this study employed the VECM to obtain long-run and short-run estimates, and the results are reported in Table 6.

Table 5. Cointegration rank test (Trace) and rank test (maximum Eigenvalue).

	Model 1				Model 2			
Unrestricted Cointegration Rank Test (Trace)								
No. of CE(s)	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**	**Prob.****	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**	**Prob.****
None *	0.536276	301.7736	125.6154	0.0000	0.868	235.301	125.615	0.000
At most 1 *	0.4149	172.671	95.753	0.0000	0.768	154.343	95.754	0.000
At most 2 *	0.2024	82.619	69.818	0.003	0.649	95.968	69.819	0.000
At most 3	0.1184	44.623	47.856	0.097	0.463	54.132	47.856	0.012
At most 4	0.1003	23.451	29.797	0.224	0.383	29.266	29.797	0.058
At most 5	0.0326	5.6915	15.494	0.731	0.165	9.966	15.495	0.283
At most 6	0.0006	0.1168	3.8414	0.732	0.067	2.774	3.841	0.096
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)								
Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**	**Prob.****	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**	**Prob.****
None *	0.5362	129.10	46.231	0.0000	0.868	80.959	46.231	0.000
At most 1 *	0.4149	90.051	40.077	0.0000	0.768	58.374	40.078	0.000
At most 2 *	0.2024	37.996	33.876	0.0152	0.649	41.837	33.877	0.005
At most 3	0.1184	21.172	27.584	0.2659	0.463	24.866	27.584	0.107
At most 4	0.1003	17.759	21.131	0.1391	0.383	19.300	21.132	0.089
At most 5	0.0326	5.5746	14.264	0.6682	0.165	7.192	14.265	0.467
At most 6	0.0006	0.1168	3.841	0.7324	0.067	2.774	3.841	0.096

Note: * denotes rejection of the null hypothesis at the 0.05 level, ** MacKinnon-Haug-Michelis (1999) *p*-values.

Table 6. Vector Error Correction Long-Run Estimates.

IVs	**Vector Error Correction Estimates β Standard Errors in ( ) and t-Statistics in [ ]** Model 1 Dep.Var: EP	Model 2 Dep.Var: OP
BD(−1)	0.056574 * (0.02472) [2.288859]	7246.393 * (2916.82) [2.48435]
NX(−1)	0.072 * (0.032) [2.25746]	14606.96 * (3586.78) [4.07244]
ER(−1)	0.1638 * (0.010) [16.38]	3964.392 * (1449.85) [2.73434]
URBAN(−1)	4.96619 * (0.59947) [8.28424]	0.242393 (0.58335) [0.41552]
EPOG(−1)	0.23285 * (0.02105) [11.0591]	−6959.943 (4238.38) [−1.642123]
CO_2 (−1)	0.00658 * (0.00196) [3.35175]	209.9096 (142.460) [1.473463]
C	24.61998	6.67372.9
ECM	−0.14557 (0.01878) [−7.7513]	−0.345001 (0.06990) [−4.935636]

Note: * indicate significance at a level of less than 0.05.

The results of the vector error correction long-run estimates are reported in Table 6 and results indicate that budget and trade deficits have a significant and positive association with energy inflation (β = 0.056574 *; β = 7246.393 * and β = 0.072 *; β = 14606.96 *). Results indicate that as the twin deficit increases, it causes an increase in energy inflation. However, the size impact of the twin deficit is greater on oil prices as compared to electricity prices. Our results are consistent with El Anshasy and Bradley [58] who stated that when government expenditure increases and revenue decreases, the government will finance this fiscal deficit by increasing the electricity prices and oil prices.

Similarly, results indicate that ER has a significant and positive long-run association with electricity prices and oil prices (β = 0.1638 *; β = 3964.392 *). The results of the study also confirm that the size of the impact of ER on oil prices is greater as compared to the impact of ER on electricity prices. Our results contradict Amano and Van Norden [64] who stated that an increase in oil prices will cause an increase in the trade deficit in developing nations. Furthermore, urbanization (URBAN) has a positive and significant long-run association with energy inflation in terms of EP, while URBAN has an insignificant association with oil prices (β = 4.96619 *; β = 0.242393). Similarly, EPOG and CO_2 have a positive and significant long-run association with EP (β = 0.23285 *; β = 0.00658 *). The error correction term (ECM) indicates that the speed of convergence in Model 1 is 14% in one quarter, while in Model 2 the convergence speed is 34%.

Additionally, the vector error correction short-run estimates (Model 1) are reported in Table A1 (see Appendix A). Results indicate that electricity prices are positively and significantly associated with ER and urbanization in the short-run period. Moreover, ER and urbanization have a positive and significant association with ER in the short-run period. Similarly, urbanization has a positive and significant association with urbanization in the short-run period.

The vector error correction short-run estimates (Model 2) are reposted in Table A2 (see Appendix A). Results indicate that oil prices are negatively and significantly associated with ER while BD has a positive and significant association with urbanization in the short-run period. Moreover, the trade deficit has a positive and significant association with NX and ER in the short-run period while CO_2 emission has a negative and significant association with ER in the short-run period.

Moreover, this study utilized LM tests and white noise heteroskedasticity tests to establish no serial correlation and no heteroskedasticity. Results are reported in Table 7 and results indicate that there is no serial correlation up to 3 lags and the data are free from heteroskedasticity.

Table 7. Residual test.

	Model 1		Model 2		
VAR Residual Serial Correlation LM Tests, Null Hypothesis: No Serial Correlation at Lag Order h					
Lags	**LM-Stat**	**Prob**	**LM-Stat**	**Prob**	
1	46.58890	0.5714	45.81160	0.6032	
2	61.86835	0.1026	59.45098	0.1457	
3	23.73880	0.9991	44.16532	0.6691	
VAR Residual Heteroskedasticity Tests: Null Hypothesis: No Cross Terms (only levels and squares)					
Chi-sq	**df**	**Prob.**	**Chi-sq**	**df**	**Prob.**
646.3881	784	0.9999	830.1378	840	0.5891

4.3. Variance Decomposition

The percentage of innovation that each variable contributes to the other variables in the VAR system is measured via variance decomposition. Variance decomposition is used to examine whether variables are relatively endogenous or exogenous in the VAR system. The results of variance decomposition are reported in Table 8. Periods 1 and 2 indicate the short-run relative contribution of the variable in energy inflation while periods 9 and 10 indicate the contribution of the variable in energy inflation in the long-run period.

The following research questions were addressed using the variance decomposition technique:

1. What is the relative contribution of the budget deficit to energy inflation?
2. What is the relative contribution of the trade deficit to energy inflation?
3. What is the relative contribution of the exchange rate to energy inflation?
4. What is the relative contribution of electricity production from oil and gas to energy inflation?
5. What is the relative contribution of climate change to energy inflation?

Table 8. Variance decomposition.

Period	S.E.	EP	BD	NX	ER	URBAN	EPOG	CO_2
				Model 1				
1	0.188	100	0	0	0	0	0	0
2	0.265	90.870	2.900	1.100	2.051	1.044	1.020	1.014
3	0.324	85.718	4.000	2.000	3.108	1.097	2.038	2.040
4	0.374	79.580	5.001	3.699	3.182	2.116	3.349	3.072
5	0.419	75.600	6.000	4.000	4.364	3.095	3.867	4.073
6	0.460	72.601	6.001	4.100	4.551	3.982	3.994	4.771
7	0.498	60.581	10.001	8.001	5.147	4.076	7.122	5.072
8	0.533	53.149	13.001	9.001	5.352	6.075	8.145	5.277
9	0.566	46.234	15.002	11.001	5.447	7.069	9.169	6.079
10	0.598	38.52	15.001	13.001	6.141	9.063	10.195	8.079
				Model 2				
Period	**S.E.**	**OP**	**BD**	**NX**	**ER**	**CO_2**	**EPOG**	**URBAN**
1	15812.100	100.000	0.000	0.000	0.000	0.000	0.000	0.000
2	24761.160	96.895	0.607	0.029	1.013	0.959	0.008	0.489
3	33910.120	93.974	2.035	0.078	0.573	2.499	0.580	0.261
4	39682.380	92.857	2.517	0.071	0.690	2.840	0.832	0.194
5	44633.900	90.952	3.022	0.147	0.580	3.449	1.680	0.171
6	49249.720	90.107	3.026	0.126	0.486	4.208	1.900	0.147
7	53851.760	89.083	2.988	0.115	0.423	5.019	2.244	0.129
8	57781.200	88.082	3.112	0.100	0.367	5.634	2.590	0.114
9	61412.540	86.980	3.342	0.089	0.328	6.099	3.059	0.104
10	64838.850	85.977	3.535	0.096	0.294	6.520	3.483	0.094

The results of the variance decomposition test (Table 8) indicate that in the first quarter electricity prices contribute 100% to electricity prices, while other factors have no contribution, but in the long run, its relative contribution declined up to 38% in Model 1, while in Model 2, for oil prices, it declined up to 85%. Moreover, results indicate that in Model 1, the long-run relative contribution of BD, NX, ER, URBAN, EPOG, and EC in electricity prices is 15.001%, 13.001%, 6.141%, 9.063%, 10.195%, and 8.079%, respectively. The results of Model 1 indicate that the relative contribution of the budget deficit is greater than other exogenous variables. In Model 2, the relative contribution of BD, NX, ER, EC, EPOG, and URBAN in oil prices, in the long run, is 3.535%, 0.096%, 0.294%, 6.520%, 3.483%, and 0.094%, respectively, and results indicate that the relative contribution of BD and EC is greater in oil prices as compared to other exogenous variables.

Moreover, in Figure 1, the AR roots graph results show that the data are normally distributed as the blue dots are in the circle and no outlier exists in the data.

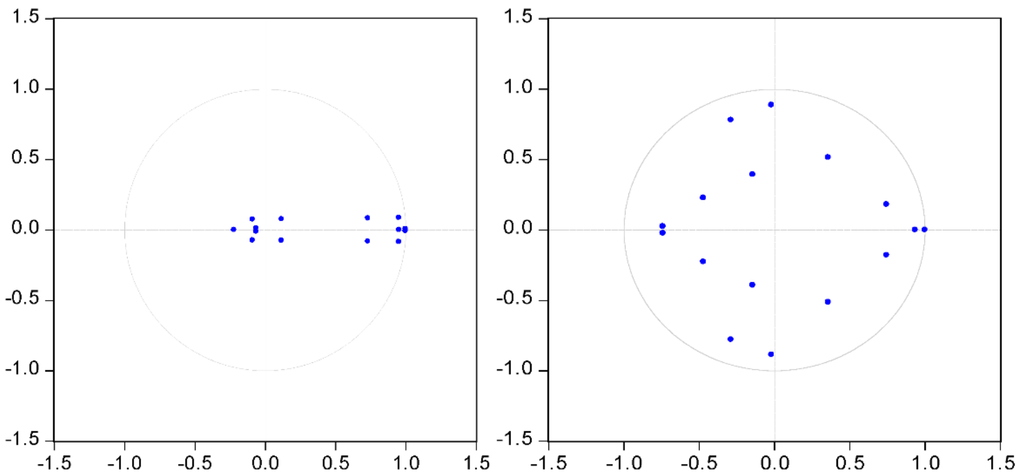

Figure 1. Inverse root of AR characteristics polynomial.

4.4. Impulse Response

In practical research, the impulse response function is used to enhance the credibility of VAR econometrics and the impulse response function shows a graphical representation of one standard positive or negative shock to one variable and its impact on other series in the VAR system [65].

The following research queries are addressed by computing generalized impulse response functions (GIRFs):

1. What is the response of energy inflation in time t + n when one standard shock is given to the VAR system of the budget deficit at time t while no other shock hits the system?
2. What is the response of energy inflation in time t + n when one standard shock is given to the VAR system of trade deficit at time t while no other shock hits the system?
3. What is the response of energy inflation in time t + n when one standard shock is given to the VAR system of energy production from oil and gas at time t while no other shock hits the system?
4. What is the response of energy inflation in time t + n when one standard shock is given to the VAR system of CO_2 at time t while no other shock hits the system?

Figures 2 and 3 indicate how the endogenous variable responds in time t + 1 when one standard positive or negative shock is given to the exogenous variable in the VAR system.

Figure 2 indicates that one standard positive/negative shock to the trade deficit and the exchange rate will bring a positive impact on electricity prices in the forecasted 10 quarters while one standard positive/negative shock to the budget deficit will bring a positive impact on electricity prices up to the fifth quarter, becoming negative after that.

Similarly, Figure 3 indicates that one standard positive/negative shock to the budget deficit, trade deficit, and the exchange rate will bring a positive impact on oil prices in the forecasted period.

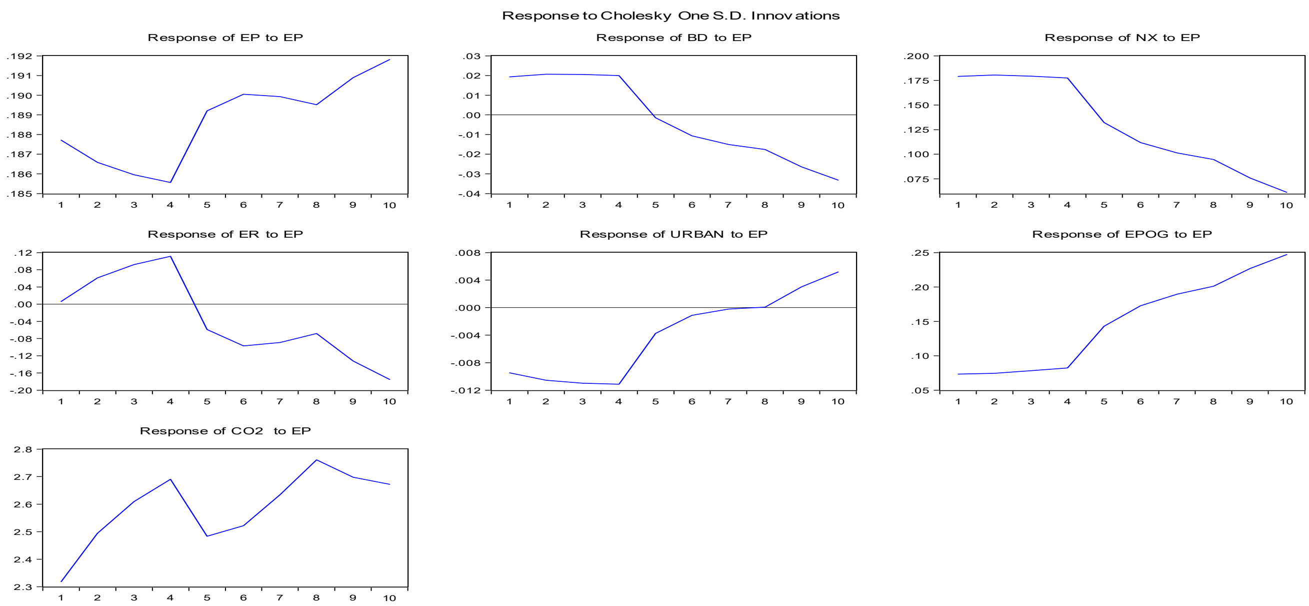

Figure 2. Impulse response (Model 1).

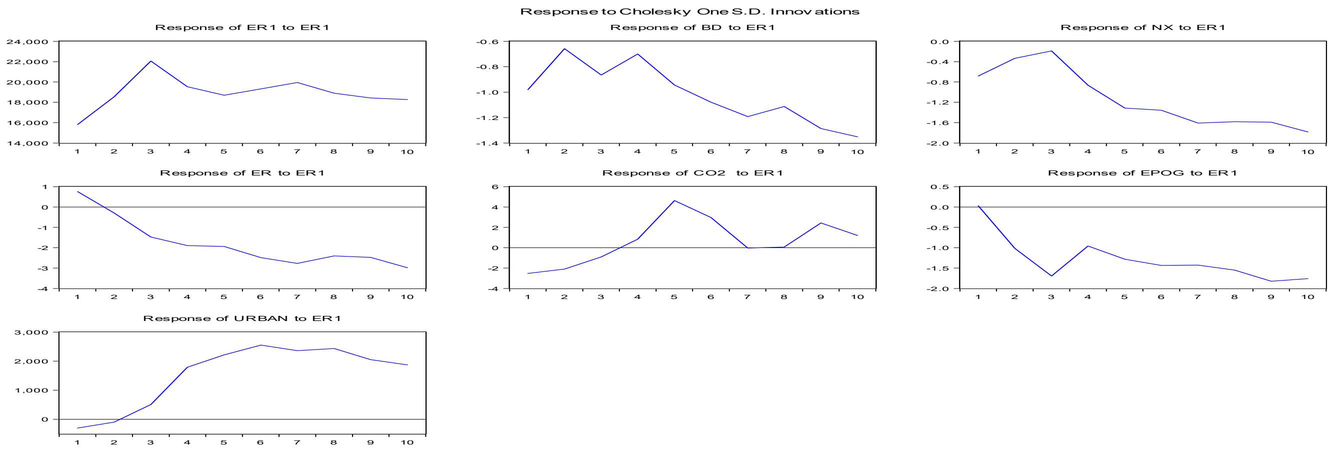

Figure 3. Impulse response (Model 2).

5. Conclusions and Policy Suggestions

The main contribution of the study is to investigate the long-run association of twin deficits (budget deficit and trade deficit), urbanization, climate change, the exchange rate, and energy production from oil and gas and energy inflation. In comparison to most recent studies [66], our model specification and approach with original empirical results provide the main novelty.

This study utilized quarterly time series data for the period of 1972 to 2021 and the data of all the variables were collected from WDI and the Census of Electricity Establishment (CEE). This study estimated two empirical models. In Model 1, electricity prices were utilized to capture the concept of energy inflation, while in Model 2, oil prices were utilized to measure energy inflation, with twin deficit (budget deficit and trade deficit), urbanization, climate change, exchange rate, and energy production from oil and gas used as independent variables in the empirical models.

This study found that budget and trade deficits have a significant and positive association with energy inflation. However, the size impact of the twin deficit is greater on oil prices as compared to electricity prices. Similarly, results indicate that the exchange rate has a significant and positive long-run association with electricity prices and oil prices, and the results of the study also confirm that the size of the impact of the exchange rate on oil prices is greater compared to the impact of the exchange rate on electricity prices. Furthermore, urbanization has a positive and significant long-run association with electricity prices, while urbanization has an insignificant association with oil prices. Similarly, climate change and energy production from oil and gas have a positive and significant long-run association with electricity prices. These results and findings suggest an alternative for the establishment of the renewable energy technologies market promoting renewable sources of energy in electricity production and use [67,68].

The error correction term (ECM) indicates that the speed of convergence in Model 1 for electricity prices is 14% in one quarter and 34% in Model 2 for oil prices in one quarter, so the speed of convergence in Model 2 is greater than the speed of convergence in Model 1.

Moreover, the results of the variance decomposition test indicate that the relative contribution of the budget deficit in electricity prices is greater than other modeled variables while the relative contribution of the budget deficit and climate change is greater in oil prices as compared to other exogenous variables in the model.

Based on the above-stated conclusion, this study suggests the following policy recommendations. First, policymakers should devise policies to control the import payments and to increase the export receipt, so that the positive impact of the trade deficit can be minimized and its impact on energy prices can be controlled. Second, policymakers should increase the tax net to enhance the revenue of the government and encourage the private sector to invest in developmental projects to lower the positive impact of fiscal deficit on energy prices. Third, due to climate change, in Pakistan, demand for energy drastically increased, which put pressure on prices to increase, so to control energy inflation, the government of Pakistan should introduce different projects such as the billion trees project Tsunami afforestation in Khayber Pukhtunkhwa to improve the green environment and to control the energy demand. Fourth, renewable energy sources should be introduced to lower energy inflation. Fifth, Pakistan should explore other sources to get cheaper oil and gas from the international market. Sixth, Pakistan should encourage planned urbanization to control the energy demand. Finally, policymakers should control significant fluctuations in the exchange rate to control energy inflation.

Author Contributions: Conceptualization, S.K., F.A. and Š.B.; methodology, S.A.S. and F.A.; software, S.K.; validation, S.K., S.A.S. and F.A.; formal analysis, S.K and F.A.; investigation, F.A.; resources, S.K. and Š.B.; data curation, S.A.S.; writing—original draft preparation, S.K.; writing—review and editing, S.K., S.A.S. and Š.B.; visualization, F.A.; supervision, S.K. and Š.B.; project administration, S.A.S.; funding acquisition, F.A. and Š.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data used in this study are in the public domain, and the relevant sources are cited in the text.

Acknowledgments: The authors would like to thank the Development, Policy, Practice, and Research Centre (DPPRC) Pakistan for the technical support in the completion of this project.

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

Appendix A

Table A1. Vector error correction short-run estimates.

Error Correction:	D(EP)	D(BD)	D(NX)	D(ER)	D(URBAN)	D(EPOG)	D(CO_2)
CointEq1	0.14557	−0.103009	−0.221636	−0.675043	0.033337	0.306416	−0.474948
	(0.01878)	(0.09480)	(0.12296)	(0.17343)	(0.00349)	(0.19442)	(0.80133)
	[7.7531]	[−1.08662]	[−1.80248]	[−3.89229]	[9.56417]	[1.57609]	[−0.59270]
D(EP(−1))	−0.034733	0.148873	0.299818	1.646437	−0.057799	−0.369506	3.147183
	(0.09214)	(0.46501)	(0.60316)	(0.85073)	(0.01710)	(0.95366)	(3.93072)
	[−0.37695]	[0.32015]	[0.49708]	[1.93533]	[−3.38053]	[−0.38746]	[0.80066]
D(EP(−2))	−0.034733	0.148873	0.299818	1.646437	−0.057799	−0.369506	3.147183
	(0.09214)	(0.46501)	(0.60316)	(0.85073)	(0.01710)	(0.95366)	(3.93072)
	[−0.37695]	[0.32015]	[0.49708]	[1.93533]	[−3.38053]	[−0.38746]	[0.80066]
D(EP(−3))	−0.034733	0.148873	0.299818	1.646437	−0.057799	−0.369506	3.147183
	(0.09214)	(0.46501)	(0.60316)	(0.85073)	(0.01710)	(0.95366)	(3.93072)
	[−0.37695]	[0.32015]	[0.49708]	[1.93533]	[−3.38053]	[−0.38746]	[0.80066]
D(BD(−1))	−0.0000498	0.000594	0.001330	0.002220	−0.000168	−0.001950	−0.003399
	(0.01678)	(0.08470)	(0.10986)	(0.15495)	(0.00311)	(0.17370)	(0.71594)
	[−0.00297]	[0.00702]	[0.01210]	[0.01433]	[−0.05404]	[−0.01123]	[−0.00475]

Table A1. *Cont.*

Error Correction:	D(EP)	D(BD)	D(NX)	D(ER)	D(URBAN)	D(EPOG)	D(CO_2)
D(BD(−2))	−0.0000498	0.000594	0.001330	0.002220	−0.000168	−0.001950	−0.003399
	(0.01678)	(0.08470)	(0.10986)	0.15495)	(0.00311)	(0.17370)	(0.71594)
	[−0.00297]	[0.00702]	[0.01210]	[0.01433]	[−0.05404]	[−0.01123]	[−0.00475]
D(BD(−3))	−0.0000498	0.000594	0.001330	0.002220	−0.000168	−0.001950	−0.003399
	(0.01678)	(0.08470)	(0.10986)	(0.15495)	(0.00311)	(0.17370)	(0.71594)
	[−0.00297]	[0.00702]	[0.01210]	[0.01433]	[−0.05404]	[−0.01123]	[−0.00475]
D(NX(−1))	0.000262	−0.004022	−0.009112	−0.011370	0.001087	0.013603	0.036435
	(0.01402)	(0.07075)	(0.09177)	(0.12944)	(0.00260)	(0.14511)	(0.59808)
	[0.01872]	[−0.05685]	[−0.09929]	[−0.08784]	[0.41775]	[0.09375]	[0.06092]
D(NX(−2))	0.000262	−0.004022	−0.009112	−0.011370	0.001087	0.013603	0.036435
	(0.01402)	(0.07075)	(0.09177)	(0.12944)	(0.00260)	(0.14511)	(0.59808)
	[0.01872]	[−0.05685]	[−0.09929]	[−0.08784]	[0.41775]	[0.09375]	[0.06092]
D(NX(−3))	0.000262	−0.004022	−0.009112	−0.011370	0.001087	0.013603	0.036435
	(0.01402)	(0.07075)	(0.09177)	(0.12944)	(0.00260)	(0.14511)	(0.59808)
	[0.01872]	[−0.05685]	[−0.09929]	[−0.08784]	[0.41775]	[0.09375]	[0.06092]
D(ER(−1))	0.003489	−0.004438	−0.005266	−0.169252	0.003446	−0.002121	−0.534621
	(0.00893)	(0.04504)	(0.05842)	(0.08240)	(0.00166)	(0.09237)	(0.38073)
	[0.39090]	[−0.09854]	[−0.09014]	[−2.05399]	[2.08103]	[−0.02296]	[−1.40420]
D(ER(−2))	0.003489	−0.004438	−0.005266	−0.169252	0.003446	−0.002121	−0.534621
	(0.00893)	(0.04504)	(0.05842)	(0.08240)	(0.00166)	(0.09237)	(0.38073)
	[0.39090]	[−0.09854]	[−0.09014]	[−2.05399]	[2.08103]	[−0.02296]	[−1.40420]
D(ER(−3))	0.003489	−0.004438	−0.005266	−0.169252	0.003446	−0.002121	−0.534621
	(0.00893)	(0.04504)	(0.05842)	(0.08240)	(0.00166)	(0.09237)	(0.38073)
	[0.39090]	[−0.09854]	[−0.09014]	[−2.05399]	[2.08103]	[−0.02296]	[−1.40420]
D(URBAN(−1))	−0.131836	0.852571	1.817400	6.143379	−0.283892	−2.475277	5.971596
	(0.43194)	(2.17981)	(2.82741)	(3.98789)	(0.08015)	(4.47042)	(18.4258)
	[−0.30522]	[0.39112]	[0.64278]	[1.54051]	[−3.54211]	[−0.55370]	[0.32409]
D(URBAN(−2))	−0.131836	0.852571	1.817400	6.143379	−0.283892	−2.475277	5.971596
	(0.43194)	(2.17981)	(2.82741)	(3.98789)	(0.08015)	(4.47042)	(18.4258)
	[−0.30522]	[0.39112]	[0.64278]	[1.54051]	[−3.54211]	[−0.55370]	[0.32409]
D(URBAN(−3))	−0.131836	0.852571	1.817400	6.143379	−0.283892	−2.475277	5.971596
	(0.43194)	(2.17981)	(2.82741)	(3.98789)	(0.08015)	(4.47042)	(18.4258)
	[−0.30522]	[0.39112]	[0.64278]	[1.54051]	[−3.54211]	[−0.55370]	[0.32409]
D(EPOG(−1))	0.001318	−0.008989	−0.019270	−0.061247	0.002943	0.026485	−0.050020
	(0.00907)	(0.04577)	(0.05937)	(0.08373)	(0.00168)	(0.09386)	(0.38687)
	[0.14533]	[−0.19641]	[−0.32461]	[−0.73147]	[1.74872]	[0.28217]	[−0.12929]
D(EPOG(−2))	0.001318	−0.008989	−0.019270	−0.061247	0.002943	0.026485	−0.050020
	(0.00907)	(0.04577)	(0.05937)	(0.08373)	(0.00168)	(0.09386)	(0.38687)
	[0.14533]	[−0.19641]	[−0.32461]	[−0.73147]	[1.74872]	[0.28217]	[−0.12929]

Table A1. *Cont.*

Error Correction:	D(EP)	D(BD)	D(NX)	D(ER)	D(URBAN)	D(EPOG)	D(CO_2)
D(EPOG(−3))	0.001318	−0.008989	−0.019270	−0.061247	0.002943	0.026485	−0.050020
	(0.00907)	(0.04577)	(0.05937)	(0.08373)	(0.00168)	(0.09386)	(0.38687)
	[0.14533]	[−0.19641]	[−0.32461]	[−0.73147]	[1.74872]	[0.28217]	[−0.12929]
D(CO_2 (−1))	0.000521	0.001048	0.003257	−0.025918	0.000131	−0.006703	−0.115438
	(0.00205)	(0.01033)	(0.01340)	(0.01890)	(0.00038)	(0.02119)	(0.08733)
	[0.25462]	[0.10146]	[0.24308]	[−1.37127]	[0.34469]	[−0.31634]	[−1.32186]
D(CO_2(−2))	0.000521	0.001048	0.003257	−0.025918	0.000131	−0.006703	−0.115438
	(0.00205)	(0.01033)	(0.01340)	(0.01890)	(0.00038)	(0.02119)	(0.08733)
	[0.25462]	[0.10146]	[0.24308]	[−1.37127]	[0.34469]	[−0.31634]	[−1.32186]
D(CO_2 (−3))	0.000521	0.001048	0.003257	−0.025918	0.000131	−0.006703	−0.115438
	(0.00205)	(0.01033)	(0.01340)	(0.01890)	(0.00038)	(0.02119)	(0.08733)
	[0.25462]	[0.10146]	[0.24308]	[−1.37127]	[0.34469]	[−0.31634]	[−1.32186]
C	−0.024359	0.019114	0.008707	1.186106	−0.021398	0.059120	3.979538
	(0.02019)	(0.10191)	(0.13219)	(0.18645)	(0.00375)	(0.20901)	(0.86146)
	[−1.20623]	[0.18755]	[0.06587]	[6.36167]	[−5.71059]	[0.28286]	[4.61952]
R-squared	0.7431	0.81071	0.22432	0.166204	0.399480	0.018382	0.064150
Adj. R-squared	0.4316	0.42387	0.12588	0.039697	0.308367	0.130553	0.077841
F-statistic	49.346	5.3869	15.1239	1.313790	4.384433	3.123421	2.451787

Table A2. Vector error correction long-run estimates (Model 2).

Error Correction:	D(OP)	D(BD)	D(NX)	D(ER)	D(EPOG)	D(URBAN)
CointEq1	−0.45001	−0.0000169	−0.0000271	−0.0000206	−0.0000110	−0.025245
	(0.06990)	(0.0000078)	(0.0000077)	(0.0000069)	(0.000015)	(0.01800)
	[−6.4379]	[−2.17629]	[−3.53997]	[−2.97487]	[−0.73120]	[−1.40278]
D(OP(−1))	0.251186	0.0000160	0.00000282	−0.0000510	−0.00006	0.081222
	(0.21545)	(0.000024)	(0.000024)	(0.00002)	(0.000047)	(0.05547)
	[1.16586]	[0.66555]	[0.11958]	[−2.38782]	[−1.45364]	[1.46420]
D(OP(−2))	0.086559	−0.0000197	0.0000358	−0.0000447	−0.0000238	0.071073
	(0.25768)	(0.000029)	0.000028)	(0.000026)	(0.000056)	(0.06634)
	[0.33592]	[−0.68754]	[1.26672]	[−1.74971]	[−0.04277]	[1.07129]
D(BD(−1))	938.9356	−0.294968	−0.212366	0.347850	−0.406391	1102.980
	(2047.74)	(0.22810)	(0.22431)	(0.20307)	(0.44265)	(527.228)
	[0.45852]	[−1.29314]	[−0.94676]	[1.71297]	[−0.91809]	[2.09204]
D(BD(−2))	−3394.361	0.042269	−0.019682	0.140159	0.331649	1197.757
	(2310.32)	(0.25735)	(0.25307)	(0.22911)	(0.49941)	(594.834)
	[−1.46922]	[0.16425]	[−0.07777]	[0.61176]	[0.66408]	[2.01360]
D(NX(−1))	1085.011	−0.050749	−0.011413	0.015141	0.498113	−521.0790
	(1360.63)	(0.15156)	(0.14904)	(0.13493)	(0.29412)	(350.318)
	[0.79744]	[−0.33484]	[−0.07657]	[0.11221]	[1.69358]	[−1.48744]

Table A2. *Cont.*

Error Correction:	D(OP)	D(BD)	D(NX)	D(ER)	D(EPOG)	D(URBAN)
D(NX(−2))	−618.6136	0.070703	−0.466387	0.329027	0.518213	−76.23325
	(1486.66)	(0.16560)	(0.16285)	(0.14743)	(0.32136)	(382.768)
	[−0.41611]	[0.42695]	[−2.86396]	[2.23178]	[1.61255]	[−0.19916]
D(ER(−1))	964.0541	−0.388359	−0.077655	−0.299735	−0.133808	−480.3510
	(2093.30)	(0.23318)	(0.22930)	(0.20759)	(0.45250)	(538.958)
	[0.46054]	[−1.66552]	[−0.33867]	[−1.44390]	[−0.29571]	[−0.89126]
D(ER(−2))	−175.6366	−0.089217	−0.328683	−0.212943	−0.251320	−312.1279
	(1554.20)	(0.17313)	(0.17025)	(0.15413)	(0.33596)	(400.157)
	[−0.11301]	[−0.51533]	[−1.93064]	[−1.38162]	[−0.74806]	[−0.78001]
D(CO_2 (−1))	265.2939	−0.001391	0.014280	−0.120511	−0.024365	31.51543
	(228.784)	(0.02548)	(0.02506)	(0.02269)	(0.04945)	(58.9046)
	[1.15958]	[−0.05459]	[0.56982]	[−5.31166]	[−0.49268]	[0.53502]
D(CO_2 (−2))	240.9756	−0.045587	−0.014429	−0.075120	0.048763	−2.906087
	(297.029)	(0.03309)	(0.03254)	(0.02946)	(0.06421)	(76.4757)
	[0.81129]	[−1.37780]	[−0.44347]	[−2.55029]	[0.75947]	[−0.03800]
D(EPOG(−1))	89.31282	−0.082731	0.035870	−0.003735	−0.542841	−468.8391
	(1074.89)	(0.11973)	(0.11774)	(0.10659)	(0.23235)	(276.751)
	[0.08309]	[−0.69095]	[0.30465]	[−0.03504]	[−2.33627]	[−1.69408]
D(EPOG(−2))	5.986388	−0.009629	0.006515	0.046713	−0.064362	−273.7340
	(930.275)	(0.10363)	(0.10190)	(0.09225)	(0.20109)	(239.517)
	[0.00644]	[−0.09292]	[0.06393]	[0.50635]	[−0.32006]	[−1.14286]
D(GHGE(−1))	−0.759431	$0.00003.58 \times 10^{-05}$	−0.000333	0.000105	0.0000480	−0.095136
	(0.81470)	(0.000091)	(0.000089)	(0.000081)	(0.00018)	(0.20976)
	[−0.93216]	[0.39498]	[−3.73571]	[1.29594]	[0.27263]	[−0.45355]
D(GHGE(−2))	0.879257	−0.0000891	−0.000115	0.000107	0.0000222	0.284099
	(0.67624)	(0.000075)	(0.000074)	(0.00006)	(0.00015)	(0.17411)
	[1.30022]	[−1.18242]	[−1.55898]	[1.59586]	[0.15158]	[1.63172]
C	−865.8114	1.827340	2.732217	4.887008	1.688839	5171.900
	(10037.6)	(1.11811)	(1.09951)	(0.99540)	(2.16978)	(2584.37)
	[−0.08626]	[1.63431]	[2.48494]	[4.90957]	[0.77835]	[2.00122]
R-squared	0.444381	0.414427	0.643703	0.837654	0.437262	0.665013
Adj. R^2	0.397119	0.348444	0.421018	0.736187	0.085550	0.455645
F-statistic	1.279671	1.132368	2.890637	8.255475	1.243240	3.176298

Appendix A.1 Specific VAR Econometric Models

Vector Auto regression (**VAR**) is a stochastic process model that generalize the single variable auto regressive model by allowing multivariate time series. The two equations below are for electricity and oil prices as dependent variables, respectively.

$$\Delta EP_{it} = \propto_{1j} + \gamma_{1i} ECT_{it-1} + \sum_{k=1}^{m} \beta_{11ik}\, \Delta BD_{it-k} + \sum_{k=1}^{m} \beta_{12ik}\, \Delta NX_{it-k} + \sum_{k=1}^{m} \beta_{13ik}\, \Delta URBAN_{it-k} + \sum_{k=1}^{m} \beta_{14ik}\, \Delta ER_{it-k} + \sum_{k=1}^{m} \beta_{15ik}\, \Delta\, CO_{2it-k} + \sum_{k=1}^{m} \beta_{16ik}\, \Delta EPOG_{it-k} + \varepsilon_{1it} \quad (A1)$$

$$\Delta OP_{it} = \propto_{1j} + \gamma_{1i} ECT_{it-1} + \sum_{k=1}^{m} \beta_{11ik}\, \Delta BD_{it-k} + \sum_{k=1}^{m} \beta_{12ik}\, \Delta NX_{it-k} + \sum_{k=1}^{m} \beta_{13ik}\, \Delta URBAN_{it-k} + \sum_{k=1}^{m} \beta_{14ik}\, \Delta ER_{it-k} + \sum_{k=1}^{m} \beta_{15ik}\, \Delta\, CO_{2it-k} + \sum_{k=1}^{m} \beta_{16ik}\, \Delta EPOG_{it-k} + \varepsilon_{1it} \tag{A2}$$

Appendix A.2 System of VAR Models

This study developed system of VAR model to capture the relationship between multiple series as they change over time. This is presented for each of the studied 14 variables in a separate equation below:

$$\Delta EP_{it} = \propto_{1j} + \gamma_{1i} ECT_{it-1} + \sum_{k=1}^{m} \beta_{11ik}\, \Delta BD_{it-k} + \sum_{k=1}^{m} \beta_{12ik}\, \Delta NX_{it-k} + \sum_{k=1}^{m} \beta_{13ik}\, \Delta URBAN_{it-k} + \sum_{k=1}^{m} \beta_{14ik}\, \Delta ER_{it-k} + \sum_{k=1}^{m} \beta_{15ik}\, \Delta\, CO_{2it-k} + \sum_{k=1}^{m} \beta_{16ik}\, \Delta EPOG_{it-k} + \varepsilon_{1it} \tag{A3}$$

$$\Delta BD_{it} = \propto_{1j} + \gamma_{1i} ECT_{it-1} + \sum_{k=1}^{m} \beta_{11ik}\, \Delta EP_{it-k} + \sum_{k=1}^{m} \beta_{12ik}\, \Delta NX_{it-k} + \sum_{k=1}^{m} \beta_{13ik}\, \Delta URBAN_{it-k} + \sum_{k=1}^{m} \beta_{14ik}\, \Delta ER_{it-k} + \sum_{k=1}^{m} \beta_{15ik}\, \Delta\, CO_{2it-k} + \sum_{k=1}^{m} \beta_{16ik}\, \Delta EPOG_{it-k} + \varepsilon_{1it} \tag{A4}$$

$$\Delta NX_{it} = \propto_{1j} + \gamma_{1i} ECT_{it-1} + \sum_{k=1}^{m} \beta_{11ik}\, \Delta EP_{it-k} + \sum_{k=1}^{m} \beta_{12ik}\, \Delta BD_{it-k} + \sum_{k=1}^{m} \beta_{13ik}\, \Delta URBAN_{it-k} + \sum_{k=1}^{m} \beta_{14ik}\, \Delta ER_{it-k} + \sum_{k=1}^{m} \beta_{15ik}\, \Delta\, CO_{2it-k} + \sum_{k=1}^{m} \beta_{16ik}\, \Delta EPOG_{it-k} + \varepsilon_{1it} \tag{A5}$$

$$\Delta URBAN_{it} = \propto_{1j} + \gamma_{1i} ECT_{it-1} + \sum_{k=1}^{m} \beta_{11ik}\, \Delta EP_{it-k} + \sum_{k=1}^{m} \beta_{12ik}\, \Delta BD_{it-k} + \sum_{k=1}^{m} \beta_{13ik}\, \Delta NX_{it-k} + \sum_{k=1}^{m} \beta_{14ik}\, \Delta ER_{it-k} + \sum_{k=1}^{m} \beta_{15ik}\, \Delta\, CO_{2it-k} + \sum_{k=1}^{m} \beta_{16ik}\, \Delta EPOG_{it-k} + \varepsilon_{1it} \tag{A6}$$

$$\Delta ER_{it} = \propto_{1j} + \gamma_{1i} ECT_{it-1} + \sum_{k=1}^{m} \beta_{11ik}\, \Delta EP_{it-k} + \sum_{k=1}^{m} \beta_{12ik}\, \Delta BD_{it-k} + \sum_{k=1}^{m} \beta_{13ik}\, \Delta NX_{it-k} + \sum_{k=1}^{m} \beta_{14ik}\, \Delta URBAN_{it-k} + \sum_{k=1}^{m} \beta_{15ik}\, \Delta\, CO_{2it-k} + \sum_{k=1}^{m} \beta_{16ik}\, \Delta EPOG_{it-k} + \varepsilon_{1it} \tag{A7}$$

$$\Delta CO_{2it} = \propto_{1j} + \gamma_{1i} ECT_{it-1} + \sum_{k=1}^{m} \beta_{11ik}\, \Delta EP_{it-k} + \sum_{k=1}^{m} \beta_{12ik}\, \Delta BD_{it-k} + \sum_{k=1}^{m} \beta_{13ik}\, \Delta NX_{it-k} + \sum_{k=1}^{m} \beta_{14ik}\, \Delta URBAN_{it-k} + \sum_{k=1}^{m} \beta_{15ik}\, \Delta ER_{it-k} + \sum_{k=1}^{m} \beta_{16ik}\, \Delta EPOG_{it-k} + \varepsilon_{1it} \tag{A8}$$

$$\Delta EPOG_{it} = \propto_{1j} + \gamma_{1i} ECT_{it-1} + \sum_{k=1}^{m} \beta_{11ik}\, \Delta EP_{it-k} + \sum_{k=1}^{m} \beta_{12ik}\, \Delta BD_{it-k} + \sum_{k=1}^{m} \beta_{13ik}\, \Delta NX_{it-k} + \sum_{k=1}^{m} \beta_{14ik}\, \Delta URBAN_{it-k} + \sum_{k=1}^{m} \beta_{15ik}\, \Delta ER_{it-k} + \sum_{k=1}^{m} \beta_{16ik}\, \Delta CO_{2it-k} + \varepsilon_{1it} \tag{A9}$$

$$\Delta OP_{it} = \propto_{1j} + \gamma_{1i} ECT_{it-1} + \sum_{k=1}^{m} \beta_{11ik}\, \Delta BD_{it-k} + \sum_{k=1}^{m} \beta_{12ik}\, \Delta NX_{it-k} + \sum_{k=1}^{m} \beta_{13ik}\, \Delta URBAN_{it-k} + \sum_{k=1}^{m} \beta_{14ik}\, \Delta ER_{it-k} + \sum_{k=1}^{m} \beta_{15ik}\, \Delta CO_{2it-k} + \sum_{k=1}^{m} \beta_{16ik}\, \Delta EPOG_{it-k} + \varepsilon_{1it} \tag{A10}$$

$$\Delta BD_{it} = \propto_{1j} + \gamma_{1i} ECT_{it-1} + \sum_{k=1}^{m} \beta_{11ik}\, \Delta OP_{it-k} + \sum_{k=1}^{m} \beta_{12ik}\, \Delta NX_{it-k} + \sum_{k=1}^{m} \beta_{13ik}\, \Delta URBAN_{it-k} + \sum_{k=1}^{m} \beta_{14ik}\, \Delta ER_{it-k} + \sum_{k=1}^{m} \beta_{15ik}\, \Delta CO_{2it-k} + \sum_{k=1}^{m} \beta_{16ik}\, \Delta EPOG_{it-k} + \varepsilon_{1it} \tag{A11}$$

$$\Delta NX_{it} = \propto_{1j} + \gamma_{1i} ECT_{it-1} + \sum_{k=1}^{m} \beta_{11ik}\, \Delta OP_{it-k} + \sum_{k=1}^{m} \beta_{12ik}\, \Delta BD_{it-k} + \sum_{k=1}^{m} \beta_{13ik}\, \Delta URBAN_{it-k} + \sum_{k=1}^{m} \beta_{14ik}\, \Delta ER_{it-k} + \sum_{k=1}^{m} \beta_{15ik}\, \Delta CO_{2it-k} + \sum_{k=1}^{m} \beta_{16ik}\, \Delta EPOG_{it-k} + \varepsilon_{1it} \tag{A12}$$

$$\Delta URBAN_{it} = \propto_{1j} + \gamma_{1i} ECT_{it-1} + \sum_{k=1}^{m} \beta_{11ik}\, \Delta OP_{it-k} + \sum_{k=1}^{m} \beta_{12ik}\, \Delta BD_{it-k} + \sum_{k=1}^{m} \beta_{13ik}\, \Delta NX_{it-k} + \sum_{k=1}^{m} \beta_{14ik}\, \Delta ER_{it-k} + \sum_{k=1}^{m} \beta_{15ik}\, \Delta CO_{2it-k} + \sum_{k=1}^{m} \beta_{16ik}\, \Delta EPOG_{it-k} + \varepsilon_{1it} \quad (A13)$$

$$\Delta ER_{it} = \propto_{1j} + \gamma_{1i} ECT_{it-1} + \sum_{k=1}^{m} \beta_{11ik}\, \Delta OP_{it-k} + \sum_{k=1}^{m} \beta_{12ik}\, \Delta BD_{it-k} + \sum_{k=1}^{m} \beta_{13ik}\, \Delta NX_{it-k} + \sum_{k=1}^{m} \beta_{14ik}\, \Delta URBAN_{it-k} + \sum_{k=1}^{m} \beta_{15ik}\, \Delta CO_{2it-k} + \sum_{k=1}^{m} \beta_{16ik}\, \Delta EPOG_{it-k} + \varepsilon_{1it} \quad (A14)$$

$$\Delta CO_{2it} = \propto_{1j} + \gamma_{1i} ECT_{it-1} + \sum_{k=1}^{m} \beta_{11ik}\, \Delta OP_{it-k} + \sum_{k=1}^{m} \beta_{12ik}\, \Delta BD_{it-k} + \sum_{k=1}^{m} \beta_{13ik}\, \Delta NX_{it-k} + \sum_{k=1}^{m} \beta_{14ik}\, \Delta URBAN_{it-k} + \sum_{k=1}^{m} \beta_{15ik}\, \Delta ER_{it-k} + \sum_{k=1}^{m} \beta_{16ik}\, \Delta EPOG_{it-k} + \varepsilon_{1it} \quad (A15)$$

$$\Delta EPOG_{it} = \propto_{1j} + \gamma_{1i} ECT_{it-1} + \sum_{k=1}^{m} \beta_{11ik}\, \Delta OP_{it-k} + \sum_{k=1}^{m} \beta_{12ik}\, \Delta BD_{it-k} + \sum_{k=1}^{m} \beta_{13ik}\, \Delta NX_{it-k} + \sum_{k=1}^{m} \beta_{14ik}\, \Delta URBAN_{it-k} + \sum_{k=1}^{m} \beta_{15ik}\, \Delta ER_{it-k} + \sum_{k=1}^{m} \beta_{16ik}\, \Delta EC_{it-k} + \varepsilon_{1it} \quad (A16)$$

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