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An Empirical Analysis of the Effects of Energy Price Shocks for Sustainable Energy on the Macro-Economy of South Asian Countries

Arodh Lal Karn [1,*], Bhavana Raj Kondamudi [2], Ravi Kumar Gupta [3], Denis A. Pustokhin [4], Irina V. Pustokhina [5], Meshal Alharbi [6], Subramaniyaswamy Vairavasundaram [7,*], Vijayakumar Varadarajan [8,9,10] and Sudhakar Sengan [11,*]

1 Department of Financial and Actuarial Mathematics, Xi'an Jiaotong-Liverpool University, Suzhou 215123, China
2 Department of Management Studies, Institute of Public Enterprise, Hyderabad 500101, Telangana, India
3 Department of Humanities and Management Science, Madan Mohan Malaviya University of Technology, Gorakhpur 273016, Uttar Pradesh, India
4 Department of Logistics, State University of Management, 109542 Moscow, Russia
5 Department of Entrepreneurship and Logistics, Plekhanov Russian University of Economics, 117997 Moscow, Russia
6 Department of Computer Science, College of Computer Engineering and Sciences, Prince Sattam Bin Abdulaziz University, Al-Kharj 11942, Saudi Arabia
7 School of Computing, SASTRA Deemed University, Thanjavur 613401, Tamil Nadu, India
8 School of Computer Science and Engineering, University of New South Wales, Sydney 2052, Australia
9 International Division, Ajeenkya DY Patil University, Pune 412105, Maharashtra, India
10 Swiss School of Business and Management Geneva, 1213 Geneva, Switzerland
11 Department of Computer Science and Engineering, PSN College of Engineering and Technology, Tirunelveli 627152, Tamil Nadu, India
* Correspondence: alkmaithili@foxmail.com (A.L.K.); vsubramaniyaswamy@gmail.com (S.V.); sudhasengan@gmail.com (S.S.)

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Abstract: Energy prices (EPs) play an imperative role in South Asian Country (SAC) Gross Domestic Product (GDP). This research empirically examines the influence of sustainable energy price shocks (EPSs) on macroeconomic indicators. The study is to forecast the impact of EPS on macroeconomic indicators from 1980 to 2020. The analysis is carried out by employing the Vector Auto-Regression (VAR) approach. Impulse Response Functions (IRFs) results indicate that EPS decreases Gross Domestic Product (GDP). They exist in the short run and the long run. This research study's overall findings suggest that high EPSs have a negative impact on GDP. The study implies that policymakers should develop, adopt, and initiate some imperatives to control the unanticipated volatility and movements in EP. The study highlights that policy should be designed to prevent fluctuations in sustainable EP and plan conservative energy policies that motivate discovering alternative energy sources to meet increasing energy demand and improve economic growth.

Keywords: energy price; GDP; real effective exchange rate; money supply; inflation rate

1. Introduction

The cost of generating electricity, petroleum products, gasoline, heating oil, fossil fuels, or any other renewable resource used in the operation of a regional solid waste management agency is called energy price (EP). The EPSs have been an essential resource of concern globally. On the other hand, due to the high dependency on imported oil, oil-importing South Asian Countries (SACs) are the most concerned. In developing SACs such as Bangladesh, Bhutan, India, Pakistan, Nepal, and Sri Lanka, macroeconomic stability is threatened by the fluctuation of oil prices (OPs) through different countries. Sources of energy are thought to be the lifeline of any economy, not because they are essential for life but because they are one of the most important strategic advantages for the socio-economic development of SACs [1]. Energy is necessary for maintaining a consistent pace of economic growth (EG) and helps sustain domestic and commercial activities.

Energy disturbances and deficiencies result in a loss of EG and unfavourably influence social attachment in public [2]. Volatility in prices, especially the recent price hikes, draws the attention of policymakers worldwide. This rise in EP adversely affects the economic growth of oil-importing countries [3]. A surge in EP increases the operating cost of business, impacting productivity and other critical EG parameters [4]. Research also concludes that there is a negative influence of EP on macroeconomic performance [5]. Due to its scarcity, most countries import crude oil to fulfil their current demands. According to [6], energy resources in countries are finite and not distributed equally, as oil-rich countries are significantly fewer globally. These demand and supply gaps force higher EP, which affects the manufacturing and agricultural sides because the prices severely affect the production of farm inputs such as machinery and fertilizer prices. EP also affects the overall demand for goods and services.

The reasons for EPSs are, firstly, that many industries use fat as a primary input; as a result, the cost of production increases, industry production reduces, and OP increases. Secondly, due to amendments in the Terms of Trade (TOT), OPs have increased, and income is transferred to the oil-exporting countries from the oil-importing countries. Thus, the countries that import oil lose out on their actual income. Finally, increases in OP due to higher prices of petroleum products and imported goods positively impact assessment. Consequently, the central bank is forced to raise the interest rate if the wage rate is higher than expected.

On the other hand, since the 1990s, SACs, such as Pakistan, have been the embassy of energy. In 1984, nearly all petroleum was imported, with 8.8% EG annually. During 1979–1984, Pakistan was an oil-importing countries. Pakistan signed a loan agreement with the International Monetary Fund (IMF) at that time, after which the IMF pointed it out to mark the sustained development in the economy of South Asia. Nevertheless, according to the IMF, the economy of Pakistan was no longer in danger or crisis. Our review and re-examining of the impact of prices on Pakistan's gross domestic product have been prompted by price fluctuations. Pakistan depends heavily on imports of oil as an emerging economy.

Thus, when there is an inconsistent effect on OP, it reflects the share markets' positive performance. The high or low price represents high or low costs; price changes directly affect the organization's earnings. Furthermore, when energy prices rise (or fall), inflation rises (or falls). Hence, this study attempts to find the influence of sustainable EPS on the financial system of SACs. This study can help policymakers understand the relationship between sustainable EPS and EG and can aid them in acclimating to the appropriate policy mix that can aid inadequate planning.

This paper would be helpful in resolving the EP puzzle that was created for the economy. The current article refers to EPS and its connection with EG for future studies.

Methodological approaches that were applied in great detail during this research are described below:

(a) How are the sustainable energy price shocks (SEPSs) on economic and financial factors for sustainable development literary works changing from the perspective of the Intellectual Capital of Economic Growth (ICEG) factor?
(b) When it comes to SEPSs, what areas of macroeconomic performance and ICEG have been the focus of the literature thus far?
(c) What are the potential ramifications of investigating sustainable energy price shocks, ICEG technology policies, and VAR new tech policies?

The goal of the first study objective is to describe the current state of the research findings and the degree to which they take the claim into account.

The second research question focuses on the viewpoint from which the research has been developed and the fields of study that appear.

As a predictive question, the third asks the authors to discuss and talk openly about their new perspectives.

Research models are also crucial for deciding which data sources to discuss and which methodologies, resources, and operational approaches to implement during the study's design.

The organisation of this article is as follows: Section 1 is helpful in resolving the EP puzzle that was created for the economy. The current article refers to EPS and its connection with EG for future studies. Section 2 is discussed in many pieces of literature regarding the influences of EP on GDP. However, most of the literature has been absorbed over the last couple of decades. An in-depth description of the data is provided in Section 3. In Section 4, we estimate the impact of EPS on macroeconomic variables using the reduced-form model. Section 5 describes the data model and test case. Section 6 measures the performance of the energy price shock effect. Section 7 is the conclusion and future work of this research work.

2. Materials and Methods

In 1973–1974, the first oil shock piqued the interest of various researchers in the relationship between prices and the macro-economy. According to the literature survey, higher energy costs cause an increase in inflation, the stock exchange also becomes panicky as a result (when a sudden change occurs), and economic growth slows, which can combine instability in monetary and financial triggers [7]. Because of the importance of energy, the relationship between sustainable EP and the EG has grown in theoretical and experiential research over the last two decades. Energy is a vital ingredient in achieving sustainable economic growth for every nation, and it is considered the fourth pillar of the economy. Therefore, increments in EP, including prices of oil, gas, electricity, and crude oil, significantly affect any nation's GDP. Empirically and theoretically, the role of energy and higher EP on GDP is explored, but higher EP has no impact on the aggregate economy through any system (or transmission channel), especially in developing SACs.

Earlier, the theoretical work on EP and EG was performed by [8,9] and, more recently by [10]. The research by [11] investigated that with domestic EP, SACs are exceedingly reliant on imported energy related to the worldwide EP, thus weakening SACs' economy more than sustainable EPS. In recent papers [12–14], various methods have been used to check the impact of EPS on the GDP. For G7 countries, using quarterly data from 1980 to 2003 in a co-integrated framework of VAR, the effect of OP on inflation and interest rates was checked. The increase in the rate of interest affected the real economy.

To vary EPS, inflation is highly sensitive; therefore, SACs have witnessed a decline in inflation due to the plunge in EP in SACs. From July 2014–April 2015, the average value was 4.8%, the lowest INF Pakistan has experienced since 2003. The state banks of SACs are provided a chance by decreasing EP to diminish the policy rate. The reduction in Pakistan's exchange rate caused the strengthening of the USD, which contributed to a fall in imports. To explain the finding, the economists investigated their studies about the impact of global EPS on the macroeconomics of SACs over the past two decades. They used oil prices as a proxy for the EP. Positive EPS was found to cause statistically significant inflation and an increase in absolute GDP reduction.

So far, this section discussed many pieces of literature regarding the influences of EP on GDP. However, most literature has been absorbed over the last couple of decades. To provide the insights that may be missing from the recent data, economists have increasingly used long-run or historical evidence in the energy markets. For example, many researchers have focused on this recently [15–17]; more recently, the VAR model was used by [18–22] to analyse the statics. One of the advantages of using VAR is to identify the shocks, and users must prescribe the assumption in the variable and can be atheists of the long-run causality of the association. It is critical for the study to be endogenous of the relationship between EP and GDP [23].

3. Result Study

3.1. Data

An in-depth description of the data is provided in this section. Analysis and its sources are used to test stationery and interval lengths.

3.2. Data Description and Source

The analysis of the present paper is based on annual data covering the time from 1980 to 2018 for the variables EP, EXP, GDP, MS, INF, and INT. SACs' oil prices are used as a proxy for EP. All variables taken for this study are in log form. The data on gross domestic product (per capita), EP, real exchange rate, rate of interest, rate of inflation, and supply of money are considered from the survey of SAC economies, State Bank of Pakistan (SBP), indicators of the World Bank (IWB), and statistics from International Financial Services (IFS) during the period from 1980 to 2020.

3.3. Data Description and Source

The data of the time series must be constant to be consistent with the estimate of VAR. When data are not stationary, false or misleading results are produced. To check the stationarity, the tests used are Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP), which determine whether each data series has a unit root and is integrated. The variables are different until stationarity is realized in the case of a unit root [23–25].

3.4. Criterion of Akaike Information (CAI)

A suitable interval length is used to start, as the VAR model is lagging in sensitivity. To fulfil this purpose, AIC is employed. The chosen interval size minimizes AIC = lC2ln(L) + 2K1.

The total number of parameters is represented by K, while the L in order 1 represents the utmost value of the probability function. For example, as the CAI criterion is the most minor for this study, in the model of VAR, an interval length of 1 is engaged.

3.5. Selection of Lag Length

The first step in using the VAR model is determining how many and which variables should be included in the model. In addition, the primarily applicable lag length of the VAR model should be preferred. Bayesian Criterion of Information (BCI) can be considered to choose such criteria as which actions to use most of the time while deciding the lag length for the study (Equations (1) and (2)).

$$AIC_P = nLog^{\sigma^2} + 2p \quad (1)$$

$$BIC_P = nLog^{\sigma^2} + {}_pLog \quad (2)$$

4. Proposed Methodology

4.1. Specification

We estimate the impact of EPS on macroeconomic variables using the reduced-form model. The model is based on [26].

$$Y_t = A_0 + X_t B + U_t \quad (3)$$

where is a vector of (n1) endogenous variables, is a vector of (nxn) exogenous variables, and is the error term, i.e., A (0,). While "Y_t" is the GDP per capita for the nation at the start of a period worldwide, conditional convergence is taken. It is the vector of a (nx1) endogenous variable, and "X_t" is the vector of a (nxn) exogenous variable, including EP, EXP, INF, Money Supply, INT, and "U_t" is the error term, distributed with Equations (4)–(9).

$$Y_t = \widetilde{\alpha_{10}} - \beta_{11} Y_{t-1} - \beta_{12} EP_t - \beta_{13} EP_{t-1} - \beta_{14} INT_t - \beta_{15} INT_{t-1} - \beta_{16} M1_t - \beta_{17} M1_{t-1} - \beta_{18} EXP_t - \beta_{19} EXP_{t-1} - \beta_{110} INF_t - \beta_{111} INF_{t-1} - \hat{I}_{1t} \quad (4)$$

$$\mathrm{EP_t} = \widetilde{\alpha_{20}} - \beta_{21}\mathrm{Y_t} - \beta_{22}\mathrm{Y_{t-1}} - \beta_{23}\mathrm{EP_{t-1}} - \beta_{24}\mathrm{INT_t} - \beta_{25}\mathrm{INT_{t-1}} - \beta_{26}\mathrm{M1_t} - \beta_{27}\mathrm{M1_{t-1}} - \beta_{28}\mathrm{Exp_t} - \beta_{29}\mathrm{Exp_{t-1}} - \beta_{210}\mathrm{INF_t} - \beta_{211}\mathrm{INF_{t-1}} - \hat{\mathrm{I}}_{2t} \quad (5)$$

$$\mathrm{INT_t} = \widetilde{\alpha_{30}} - \beta_{31}\mathrm{Y_t} - \beta_{32}\mathrm{Y_{t-1}} - \mathrm{EP_t} - \beta_{34}\mathrm{EP_{t-1}} - \beta_{35}\mathrm{INT_{t-1}} - \beta_{37}\mathrm{M1_{t-1}} - \beta_{38}\mathrm{EXP_t} - \beta_{39}\mathrm{EXP_{t-1}} - \beta_{310}\mathrm{INF_t} - \beta_{311}\mathrm{INF_{t-1}} - \varepsilon_{3t} \quad (6)$$

$$\mathrm{M1_t} = \widetilde{\alpha_{40}} - \beta_{41}\mathrm{Y_t} - \beta_{42}\mathrm{Y_{t-1}} - \beta_{43}\mathrm{EP_t} - \beta_{44}\mathrm{EP_{t-1}} - \beta_{45}\mathrm{INT_t} - \beta_{46}\mathrm{INT_{t-1}} - \beta_{47}\mathrm{M1_{t-1}} - \beta_{48}\mathrm{EXP_t} - \beta_{49}\mathrm{EXP_{t-1}} - \beta_{410}\mathrm{INF_t} - \beta_{411}\mathrm{INF_t} - \varepsilon_{4t} \quad (7)$$

$$\mathrm{EXP_t} = \widetilde{\alpha_{50}} - \beta_{51}\mathrm{Y_t} - \beta_{52}\mathrm{Y_{t-1}} - \beta_{53}\mathrm{EP_t} - \beta_{54}\mathrm{EP_{t-1}} - \beta_{55}\mathrm{INT_t} - \beta_{56}\mathrm{INT_{t-1}} - \beta_{57}\mathrm{M1_t} - \beta_{58}\mathrm{M1_t} - \beta_{59}\mathrm{EXP_{t-1}} - \beta_{510}\mathrm{INF_t} - \beta_{511}\mathrm{INF_{t-1}} - \varepsilon_{5t} \quad (8)$$

$$\mathrm{INF_t} = \widetilde{\alpha_{60}} - \beta_{61}\mathrm{Y_t} - \beta_{62}\mathrm{Y_{t-1}} - \beta_{63}\mathrm{EP_t} - \beta_{64}\mathrm{EP_{t-1}} - \beta_{65}\mathrm{INT_t} - \beta_{66}\mathrm{INT_{t-1}} - \beta_{67}\mathrm{INT_{t-1}} - \beta_{67}\mathrm{M1_t} - \beta_{58}\beta_{68}\mathrm{M1_{t-1}} - \beta_{68}\mathrm{EXP_t} - \beta_{610}\mathrm{EXP_{t-1}} - \beta_{611}\mathrm{INF_{t-1}} - \varepsilon_{6t} \quad (9)$$

As a result of applying the contemporary variable to the LHS of Equations (10)–(14), we obtain:

$$\mathrm{Y_tECON_tINT_tM1_tEXP_tINF_t} = \begin{bmatrix} 1\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16}\beta_{21}1\beta_{23}\beta_{24}\beta_{25}\beta_{32}\beta_{12}1\beta_{34}\beta_{36}\beta_{41}\beta_{42}\beta_{43} \\ 1\beta_{45}\beta_{46}\beta_{51}\beta_{52}\beta_{53}\beta_{54}1\beta_{56}\beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}1 \end{bmatrix}^{-1} \quad (10)$$

$$[\beta_{10}\beta_{20}\beta_{30}\beta_{40}\beta_{50}\beta_{60}] + \begin{bmatrix} 11\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16}\beta_{21}\beta_{23}\beta_{24}\beta_{25}\beta_{26}\beta_{32}1\beta_{34}\beta_{35}\beta_{36}\beta_{41}\beta_{42}\beta_{43} \\ 1\beta_{45}\beta_{46}\beta_{51}\beta_{52}\beta_{53}\beta_{54}1\beta_{56}\beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}1 \end{bmatrix} \quad (11)$$

$$[\beta_{10}\beta_{20}\beta_{30}\beta_{40}\beta_{50}\beta_{60}] + [1\,{}^{\gamma_{12}\gamma_{13}\gamma_{14}\gamma_{15}\gamma_{16}\gamma_{21}\gamma_{24}\gamma_{25}\gamma_{26}\gamma_{31}\gamma_{32}\gamma_{34}\gamma_{35}\gamma_{36}\gamma_{41}\gamma_{42}\gamma_{43}}_{\gamma_{45}\gamma_{46}\gamma_{51}\gamma_{53}\gamma_{54}\gamma_{56}\gamma_{61}\gamma_{62}\gamma_{63}\gamma_{64}\gamma_{65}1}] \quad (12)$$

$$[\mathrm{Y_{t-1}ECON_{t-1}INT_{t-1}M1_{t-1}EXP_{t-1}INF_{t-1}}]\ldots + \begin{bmatrix} 1\,{}^{\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16}\beta_{21}\beta_{23}\beta_{24}\beta_{25}\beta_{26}\beta_{32}\beta_{32}1\beta_{34}\beta_{35}\beta_{36}\beta_{41}\beta_{42}}_{\beta_{43}\beta_{45}\beta_{46}\beta_{51}\beta_{52}\beta_{53}\beta_{54}\beta_{56}\beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}1} \end{bmatrix} \quad (13)$$

$$[\varepsilon_{1t}\varepsilon_{1t}\varepsilon_{1t}\varepsilon_{1t}\varepsilon_{1t}\varepsilon_{1t}] \quad (14)$$

Equations (15)–(19) stipulate the primitive VAR (p) progression, where βi is a KxK matrix of factors, β is a Kx1 vector of constants, andε is a disturbance term. In this equation, $\mathrm{Y_t}$ represents the GDP for a country at a time, while $\mathrm{Y_{t-1}}$ is the lag value (LV) of its value, and β_{10} is the intercept. $\mathrm{EP_t}$ represents EP for a country at a time while EP_{t-1} is the LV of its value. β_{11} is slope, and $\mathrm{ER_t}$ demonstrates the exchange rate, while $\mathrm{ER_{t-1}}$ represents the LV of its value. In this equation, $\mathrm{INT_t}$ is interest rate while $\mathrm{INT_{t-1}}$ is the LV of its value. Here $\mathrm{M1_t}$ shows the money demand and $\mathrm{M1_{t-1}}$ is the LV of its value, $\mathrm{INF_t}$ is the inflation rate for SACs at a time while $\mathrm{INF_{t-1}}$ is the LV of its value. In this Equation (20), e_{1t} is a disturbance term. We assume the error vectors must be zero mean, contemporaneously correlated, but not auto-correlated.

By simplifying

$$[\mathrm{Y_tECON_tINT_tM1_tEXP_tINF_t}] = [{}^{1\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16}\beta_{21}\beta_{23}\beta_{24}\beta_{25}\beta_{26}\beta_{32}\beta_{32}\beta_{34}\beta_{35}\beta_{36}\beta_{41}}_{\beta_{43}1\beta_{45}\beta_{51}\beta_{52}\beta_{53}\beta_{54}\beta_{56}\beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{64}1}]^{-1} \quad (15)$$

$$[\beta_{10}\beta_{20}\beta_{30}\beta_{40}\beta_{50}\beta_{60}] + \left[\begin{matrix} 1\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16}\beta_{21}1\beta_{23}\beta_{24}\beta_{25}\beta_{26}\beta_{32}\beta_{32} \\ 1\beta_{34}\beta_{35}\beta_{36}\beta_{42}\beta_{43}\beta_{14}1\beta_{45}\beta_{46}\beta_{51}\beta_{52}\beta_{53}\beta_{54} \\ 1\beta_{56}\beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}1 \end{matrix}\right]^{-1} \quad (16)$$

$$[1\,{}^{\gamma_{12}\gamma_{13}\gamma_{14}\gamma_{15}\gamma_{16}\gamma_{21}\gamma_{23}\gamma_{24}\gamma_{25}\gamma_{26}\gamma_{31}\gamma_{32}\gamma_{34}\gamma_{36}\gamma_{41}\gamma_{42}\gamma_{43}}_{\gamma_{45}\gamma_{46}\gamma_{51}\gamma_{52}\gamma_{53}\gamma_{54}1\gamma_{56}\gamma_{61}\gamma_{62}\gamma_{63}\gamma_{65}1}] \quad (17)$$

$$[\mathrm{Y_{t-1}ECON_{t-1}INT_{t-1}M1_{t-1}EXP_{t-1}INF_{t-1}}] + \ldots + [{}^{1\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16}\beta_{21}1\beta_{23}\beta_{24}\beta_{25}\beta_{26}\beta_{32}\beta_{32}}_{1\beta_{34}\beta_{35}\beta_{36}\beta_{41}\beta_{42}\beta_{43}1\beta_{45}\beta_{46}\beta_{51}\beta_{52}\beta_{53}\beta_{54}1\beta_{56}\beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}1}][\varepsilon_{1t}\varepsilon_{1t}\varepsilon_{1t}\varepsilon_{1t}\varepsilon_{1t}\varepsilon_{1t}] \quad (18)$$

Multiplying both sides by β^{-1} we obtain

$$\beta^{-1}\beta\mathrm{M_t} = \beta^{-1}\beta_0 + \beta^{-1}{}_{\gamma}\mathrm{M_{t-1}} + \beta^{-1}\varepsilon_t \quad (19)$$

Suppose

$$\beta^{-1}\beta = \mathrm{A_0}$$
$$\beta^{-1}\gamma = \mathrm{A_1}$$
$$\beta^{-1}\varepsilon_t = \mathrm{u_t}$$

The unrestricted VAR system can be expressed in a reduced form:

$$Y_t = A_0 + X_t B + \ldots + U_t \quad (20)$$

4.2. Co-Integration Analysis

In order to ascertain that the regression of the non-stationary time series does not generate spurious regression, the study conducted a co-integration analysis [27].

It can be seen from Table 1 that the system is integrated and does not generate a spurious regression. Individually, the variables in the system have unit roots, but together, the co-movement of the variables is not spurious. Thus, it is determined that the variables in the system have stable long-run equilibrium behaviour and do not wander away from each other.

Table 1. Test of Johansen co-integration.

Johansen Co-Integration Test						
No. of CE(s),	**None ****	**At most 1 ****	**At most, 2 ***	**At most, 3 *-**	**At most, 4 *p**	**At most 5 *;**
Eigenvalue	0.917299	0.694314	0.622514	0.554016	0.237178	6.6
Trace Statistic	183.365	103.6041	65.67777	34.5027	8.663607	0.00023
Critical Value at 0.05	95.75366	69.81889	47.85613	29.79707	15.49471	3.841466
Prob. **	0	0	0.0005	0.0133	0.3974	0.9897
Unrestricted Co-integration Test Rank (Maximum Eigenvalue)						
No. of CE(s)	None	At most 1	At most 2	At most, 3 *	At most, 4 *	At most, 5 *
Eigenvalue	0.917299	0.694314	0.622514	0.554016	0.237178	6.6
Max-Eigenvalue	79.76092	37.92629	31.17507	25.8391	8.663377	0.00023
Critical Value at 0.05	40.07757	33.87687	27.58434	21.13162	14.2646	3.841466
Prob. **	0	0.0155	0.0165	0.0101	0.3152	0.9897

At level 0.05, the test indicates four equations of co-integration. At the level 0.05, * represents the rejection of the hypothesis. *p*-values of ** MacKinnon–Haug–Michelis in 1999.

Table 2 shows that the unit root test results show that the unit root is present at GDP, MS, EXP, EP, and INF levels, but that it is removed later than first differencing the data while interest rates are stationary. This suggests that the order of integration among the model variables is different; hence, standard ordinary least squares regression (OLS) and co-integration estimates are inappropriate. Thus, we use VAR. Estimation errors are caused by unit roots, which are rarely removed, even with new data.

Table 2. Stationarity analysis.

Variables	**Critical Value (5%)**	**T-Statistics**		**Probability**	**Order of Integration**
		At Level	**At 1st Difference**		
GDP	−2.954021	−1.013	−3.836	0.0062 *	I(1)
Inflation	−2.951125	−2.401	−5.916	0.0000 *	I(1)
Interest Rate	−2.957110	−3.112		0.0353 **	I(0)
Money Supply	−2.954021	−2.103	−4.953	0.0003 *	I(1)
Real Exchange Rate	−2.954021	−2.063	−4.823	0.0004 *	I(1)
Energy Prices	−2.954021	−2.811	−4.598	0.0008 *	I(1)

* max, ** min.

4.3. Impulse Response Functions

From one variable to another, the shock effect of one Standard Deviation (SD) is shown by the impulse response functions in the system; as a result, empirical causal analysis is considered an essential tool. When the shocks of one variable hit the system, the impact is transmitted to all other variables, not only for the current time but sometimes for the future horizon of the forecast. The IRF sketches the collision of the one-time shock of a variable with endogenous variables in the system over the forecast horizon.

5. Data Model and Test Case

5.1. The Development of Models Based on the Data

The test case of Levelized Cost of Energy (LCOE) vs. Value-Adjusted LCOE (VALCOE) was conducted to help us quickly compare the cost of energy of different forms of energy production, such as wind, natural gas, and solar. Analysis and model computation was completed as a result of optimising and combining these data sets. The Yearly Energy Generation (YEG) for each device in both locations were first measured by combining sea state correlation and energy matrices. The LCOE and the relevant portions of the VALCOE are then computed by combining the YEG with macroeconomic indicators and, in some cases, energy generation data. Figure 1 depicts a more simplified overview of this test [28].

Alternative power generation methods can be assessed and compared using a measuring system known as the Levelized Cost of Energy (LCOE), the Levelized Energy Cost (LEC). The average cost of inventing and operating an energy-generating resource per unit of overall energy produced over an implied lifecycle is known as the LCOE of the investment. The Levelized energy cost is the average minimum price at which the power generated by the asset must be sold to offset total production costs over its lifetime. The idea of measuring a research study's Net Present Value (NPV) is related to the estimation of the LCOE. A research study's significant power market share can be tested via LCOE analysis, much such as with NPV. Whether or not a research study results in a financial gain varies depending on the LCOE. Otherwise, the manufacturer will not build the power station and will instead consider other options. One of the first basic methods collected when implementing a research design method of this type is to estimate the cost using the LCOE.

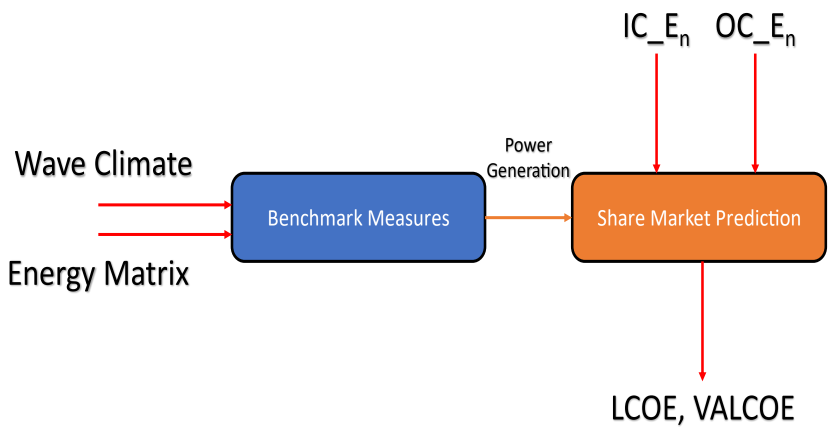


Figure 1. The LCOE vs. VALCOE contributions of energy conversion level.

The cost of designing and operating the power generation resource can be deducted to calculate the NPV, which is used to calculate the LCOE. To calculate the average income, the authors divided this measure by the aggregated power output manufactured. The total estimate of costs at the initial stage mainly includes the following: (Equations (21) and (22))

- Investment Costs (ICs);
- Operations Costs (OCs);
- Cost of Fuel (CF);

- Total Energy Produced (TEP);
- Discounted Cash Flow (DCF);
- System Lifetime (SL).

$$\mathrm{LCOE} = \frac{\mathrm{NPV} + \mathrm{IC} + \mathrm{OC} + \mathrm{SL}}{\mathrm{NPV} + \mathrm{ESP} + \mathrm{SL}} \tag{21}$$

$$\mathrm{LCOE} = \frac{\sum\left[\frac{\mathrm{IC}_{\mathrm{lt}} + \mathrm{OC}_{\mathrm{lt}} + \mathrm{CF}_{\mathrm{lt}}}{(1+\mathrm{DCF})^{\mathrm{lt}}}\right]}{\sum\left[\frac{\mathrm{TEP}_{\mathrm{lt}}}{(1+\mathrm{DCF})^{\mathrm{lt}}}\right]} \tag{22}$$

$$\begin{aligned} \textstyle\sum_{\mathrm{lt}} &= 1_{\mathrm{sl}}\mathrm{IC}_{\mathrm{lt}} \times \mathrm{LCOE}(1+\mathrm{DCF})_{\mathrm{lt}} \\ &= \mathrm{IC} + \textstyle\sum_{\mathrm{lt}}\left[1_{\mathrm{sl}}\mathrm{OC}_{\mathrm{lt}} + \mathrm{CF}_{\mathrm{lt}}(1+\mathrm{DCF})_{\mathrm{lt}}\right] \end{aligned} \tag{23}$$

5.2. Levelized Cost of Electricity

Comparing the LCOE of different power generation systems is a crucial macroeconomic factor.

Investment costs: the preliminary financial investment necessary to construct a virtual power plant

Operations costs: the OC associated with the management and operation of a virtual power plant

Fixed and variable OC: Fixed OC include salaries, security, insurance, etc., regardless of plant output. Variable OC is tied to power generation. Conventional plant fuel costs vary by production.

Budget for disposal costs: Costs associated with end-of-life are typically incurred. The costs of disposing of nuclear power plants are high. It is assumed that there are no costs associated with disposing of solar and generation projects [29,30].

Financial costs are encapsulated in the LCOE computation, as proven in the references below. The LCOE method considers tax deductions such as maintenance costs, which can provide tax savings.

When comparing generation technologies with highly variable capital costs, O and M costs, useful lives, etc., LCOE is a valuable method. LCOE is the "average" energy price a generation source needs to break even. LCOEs are used to compare emerging methods, not to make financial decisions. System planning must also consider reliability (supply during peak demand) and other factors.

Long-term planning and the fixation of economic incentives are two primary cases in which policymakers apply LCOE. Manufacturers and energy suppliers can use metrics as a planning tool to compare the preferences of multiple-generation technologies. LCOEs help investors understand long-term economic trends, especially for renewable power, whose cost decline has improved their financial viability. Consider a 100 MW wind farm to understand LCOE (Table 3).

Table 3. Test case parameters.

Parameters	Value
Total IC	USD 1400/KW
Fixed OC	USD 45/KW-year
Factor of Capacity	40%
SL	30 years
DCF	6%

By using the formulas provided, we can determine the IC and Fixed OC:

$$\text{IC} = \text{USD } 1400/\text{KW} \times 100 \text{ MW} \times 1000 \text{ KW/MW} = \text{USD } 140 \text{ million}$$

$$\text{Fixed OC} = \text{USD } 45/\text{KW/year} \times 100 \text{ MW} \times 1000 \text{ kW/MW} = \text{USD } 4.5 \text{ million/year}$$

The following is an example of the cost model for this model's level of complexity: Following is the formula used to determine the YEG of the wind farm:

$$\text{YEG} = 100 \text{ MW} \times 8760 \text{ h/year} \times 40\% = 350{,}400 \text{ MWh}$$

The NPV of the SL costs and the NPV of the SL energy generation must be equal in order to calculate the LCOE.

If all IC are made at the beginning (t = 0), and the study starts producing power overnight, as Equation (24)

$$\sum_{\text{lt}=1}^{\text{sl}} \frac{\text{TEP}_{\text{lt}} \times \text{LCOE}}{(1+\text{DCF})^{\text{lt}}} = \text{IC}_0 + \sum_{\text{lt}=1}^{\text{n}} \frac{\text{OC}_{\text{lt}} + \text{CF}_{\text{lt}}}{(1+\text{DCF})^{\text{lt}}} \tag{24}$$

In order to further simplify the Equation (25),

$$\text{LCOE} = \frac{\text{IC}_0 + \Sigma_{\text{lt}=1}^{\text{sl}} \frac{\text{OC}_{\text{t}} + \text{CF}_{\text{lt}}}{(1+\text{DCF})^{\text{lt}}}}{\Sigma_{\text{lt}=1}^{\text{sl}} \frac{\text{TEP}_{\text{t}}}{(1+\text{DCF})^{\text{lt}}}} \tag{25}$$

Given that the NVP of an annuity can be determined as

$$\text{NPV} = \frac{\text{IC}\left[1-(1+\text{DCF})^{-\text{sl}}\right]}{\text{DCF}} \tag{26}$$

After incorporating the Equation (27) for NPV into the procedure for LCOE, we obtain the following results:

$$\text{LCOE} = \frac{\text{IC}_0 + \left\{\frac{\text{OC}\times\left[1-(1+\text{DCF})^{-\text{sl}}\right]}{\text{DCF}}\right\}}{\left\{\frac{\text{TEP}\times\left[1-(1+\text{DCF})^{-\text{sl}}\right]}{\text{DCF}}\right\}} \tag{27}$$

Example of incorporating inputs from a 100 MW wind farm, Equation (28)

$$\text{LCOE} = \frac{\$140\text{MM} + 13.76 \times \$4.5\text{MM}}{350{,}400\text{MWh} \times 13.76} = \$41.87/\text{MWh} \tag{28}$$

A 20-year debt tenor and a 20-year wind farm useful life are assumed for this share price. The function calculates the LCOE so that the equity IRR equals 12%. (Table 4).

5.3. Case Study: LCOE

Table 4. Assumptions ('000s) [31].

Parameter	Value
IC (USD)	1500
OC (USD)	100

Table 4. *Cont.*

Parameter					Value						
OC Growth (%)					2.00%						
YCF (USD)					-						
YEG (KWH)					3.000						
SL (years)					10						
DCF (%)					8.00%						
Total Costs	Entry	1	2	3	4	5	6	7	8	9	10
IC	1500										
OC		-	100	102	104	106	108	110	113	115	117
CF		-	-	-	-	-	-	-	-	-	-
DCF		92.6%	85.7%	79.4%	73.5%	68.1%	63.0%	58.3%	54.0%	50.0%	46.3%
Cost of NPV	1500	-	86	81	76	72	68	64	61	57	54
Total Costs of NPV	2121 (USD)										
Total Energy	Entry	1	2	3	4	5	6	7	8	9	10
YEG	-	-	3000	3000	3000	3000	3000	3000	3000	3000	3000
DCF	-	92.6%	85.7%	79.4%	73.5%	68.1%	63.0%	58.3%	54.0%	50.0%	46.3%
Cost of NPV	-	-	2572	2381	2205	2042	1891	1750	1621	1501	1390
Total Output of NPV	17,352 kWh	-	-	-	-	-	-	-	-	-	-
LCOE	USD 0.12/kWh	-	-	-	-	-	-	-	-	-	-

5.4. Calculating the LCOE

LCOE is a system's lifetime energy cost. To calculate LCOE, divide the NPV of all costs associated with generating 1 kWh of power by the system's lifetime output. SL costs include IC, OC, and CF in Table 5 (Equation (29)).

$$\text{LCOE} = \frac{\text{SL Costs of Energy Generation System}}{\text{Overll Energy Produced with SL}} \tag{29}$$

Table 5. The formula for the LCOE.

SL Cost	Description
IC	IC needed for construction and setup
OC	Operating, servicing, and repairing a system costs
CF	Any energy-generating fuel, (coal-fired power plant coal cost)

5.5. Case Study: PV Solar Energy: An Example of the LCOE

- A SAC home appliance suggests a 6 kW microinverter solar PV system with a USD 6400 initial cost and a 25-year predicted lifespan [32];
- Let us assume for illustration's invaluable support, the 6 kW PV system (composed of 3.2 kW microinverters and 12,600 W panels) experience 5 h on average of the sun's peak daily illumination: 6 kW 5 h 365 d = 10,950 kWh/year (10.95 MWh);
- Due to module degradation, the energy generated over 25 years would be less than 10,950 kWh × 25 years. The total energy generated is 203,670 kWh or 204 MWh;
- No OCs (this is one of the major benefits of a microinverter system);
- There is no CFs present.

This solar PV system would have a LCOE of Equation (30)

$$\frac{6400}{203670} = \$0.0314/\text{kWh}(\$31.4/\text{MWh}) \tag{30}$$

- The area's electricity price is approximately USD0.212 per kWh or USD 212 per MWh.

With a 15% savings over power generation, solar is the more premium option in this case (Table 6).

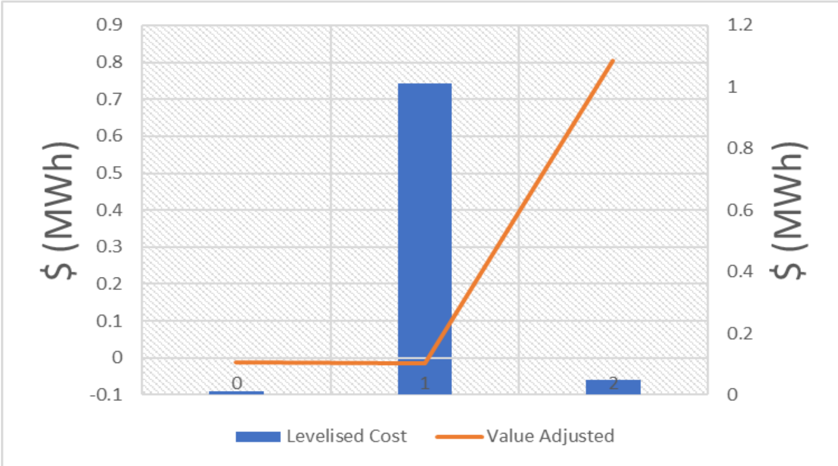
Table 6. PV solar energy LCOE.

Cost	Solar Energy Generation 2050	LCOE	Energy Stock Price
USD 6400	204 MWh	USD 31.4/MWh	USD 212/MWh

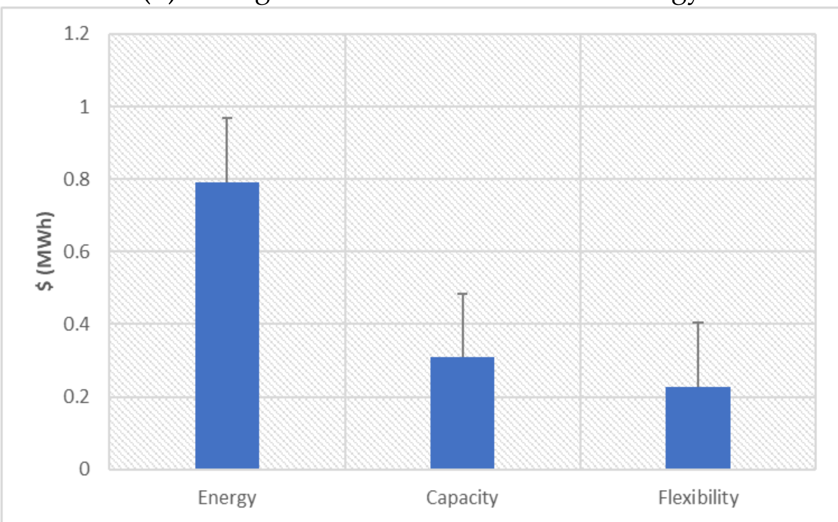
5.6. Value-Adjusted Levelized Cost of Electricity

Building on the capabilities of the Global Energy Model (GEM) hourly power supply model, the VALCOE was developed for the Global Energy Outlook (GEO)-2050 as a new metric for competitiveness for power generation technologies. It's a supplement to the LCOE, which does not take into account the product features of advanced technology but does capture relevant cost data. The LCOE reduces all direct technology costs into a single, simple metric, but it has some significant drawbacks, such as the failure to account for system value or indirect costs and the confusion of comparing technologies with various operational models. The dispatchable thermal-based technologies and measured renewables can be achieved using VALCOE, which permits benchmarks that account for cost and value.

The three value-added components of energy, capacity, and flexibility are stated for the technology-based mean LCOE to create the VALCOE. The LCOE is revised (up or down) based on how each technology's estimated cost factors compare with the system average. The VALCOE then provides a basis for analysing economic viability, with the most productive technology having the lowest number (Figure 2a,b). While energy, capacity, and flexibility services may not always be compensated for, VALCOE extends to all systems because they are all made available and essential. It takes policymakers' and planners' perspectives into account. Investors would only consider supplied revenue sources, such as tax breaks and other support policies, such as special tax provisions, so this may not reflect their views. Each technology's impact on the value adjustment varies based on operational structures and framework-specific situational factors. Technologies that can only be dispatched when there is a high demand have high costs per MWh and a relatively high value per MWh.



(**a**) Changes to the Levelized Cost of Energy



(**b**) Factors that go into determining the adjustment

Figure 2. Using the VALCOE instead of the LCOE.

Baseload technologies have small value changes because their value is typically close to the system's average. The best fit with the shape of energy consumption, the current share of renewable sources, and the generation resource input and output profile all play an essential role in the financial statements and financials for renewable energy sources subject to variation. The VALCOE can account for different operations and maintenance patterns, which improves comparisons across distributed energy technologies. The LCOE, energy, capacity, and FV make up the VALCOE. The computation is as follows: Equation (31):

$$\mathrm{VALCOE_n} = \mathrm{LCOE_n} + \frac{\text{Predictions Value}}{\text{Energy }[\mathrm{E} + \mathrm{E_n}] + \mathrm{IC}\ [\mathrm{IC} - \mathrm{IC_n}] + \text{Flexible }[\mathrm{F} - \mathrm{F_n}]} \tag{31}$$

The difference between the unit and the system average unit (E) is the adjustment for energy value (En) of a technology "n" (generation unit). The computation (En) is as shown in Equation (32):

$$\mathrm{Energy_n}\left(\frac{\$}{\mathrm{MWh}}\right) = \Sigma \frac{\text{Market Price}_\mathrm{h}\left(\frac{\$}{\mathrm{MWh}}\right) \times \mathrm{Output_{n,h}}}{\mathrm{Output_{n,h}}(\mathrm{MW})} \tag{32}$$

Every hour of the year is modelled, along with the wholesale energy prices and output volumes for each technology "n". Demand and supply pricing and other cost adders, such as operating reserve demand curves in SAC markets are not factored into wholesale prices, which are estimated primarily from the marginal cost of generation. For the SAC, hourly models are used. The adjustment for a generation unit's capacity value 'ICn' is determined (Equation (33)).

$$IC_n\left(\frac{\$}{MWh}\right) = \frac{Capacity\_Credit_n \times Basic\_Capacity\_Value}{Capactiy\_Factor_n \times \frac{Year_{hour}}{1000}} \quad (33)$$

Distinguishing between conventional and renewable technologies, the capacity credit reflects the contribution to system adequacy.

- Distribution Energy Stations = (1- a rate of technology outage);
- Renewables = technology-specific hourly modelling by region.

The highest "bid" for capacity payment determines the primary capacity value based on a simulation of the capacity market. Bids in black represent the amount of money required to cover the difference between the total cost of generation (capital recovery) and the amount of money coming in.

The capacity factor is impressive in several methods depending on the technology:

- At the starting point, renewable energy sources such as hydropower and tidal power equal the latest regional performance data and long-term averages;
- From the power seller zone, wind and solar PV are consistent with the most recent performance data from the International Renewable Energy Agency (IRENA) and other sources and are advancing due to technological advancements;
- At the consumer end, Distribution Energy Stations were previously modelled as simulated operations.

A generation unit's Flexibility Value (FV) is calculated based on Equation (34)

$$FV_x\left(\frac{\$}{MWh}\right) = \frac{FVx \times BFV\left(\frac{\$}{kW}\right)}{CF_x \times \frac{Hrs\_in\_Year}{1000}} \quad (34)$$

- The FV is multiplied by technology based on available market data and kept up-to-date over time. Targeted adjustments to virtual power plant operations do not reflect FV;
- SAC market data determines the annual share of variable renewables in the generation, which determines the base FV (BFV). Up to a maximum equal to the total fixed capital recovery costs of peak virtual power plants, the FV is assumed to rise along with rising Variable Renewable Energy (VRE) shares.

6. Performance of Energy Price Shocks Effect

The IRF for the EPS (measured by the condition of unpredictability or volatility) on GDP per capita, the real effective exchange rate, the EP, the money supply, the interest rate, and the inflation rate are provided in Table 2. For each variable, the IRF is linked separately with unit shocks that are distinguished in Figure 3. In response to a shock to sustainable EP, the GDP response is initially positive in the short run, but in the second period, it shows an adverse reaction. According to the theory, there is a negative affiliation between EP and demand, so as the EP increases, the market is low, its impact on GDP is negative, and GDP responds negatively; this graph shows that it is. The third graph demonstrates the IRF as a shock to sustainable EP. The IN, MS, and EXP responses to energy prices are also positive. EPS produces a positive reaction in EP upon the impact that then converges to equilibrium in the 4th period. However, the response of the remaining variables in the system remains stable over the entire forecast horizon for the EPS in the system.

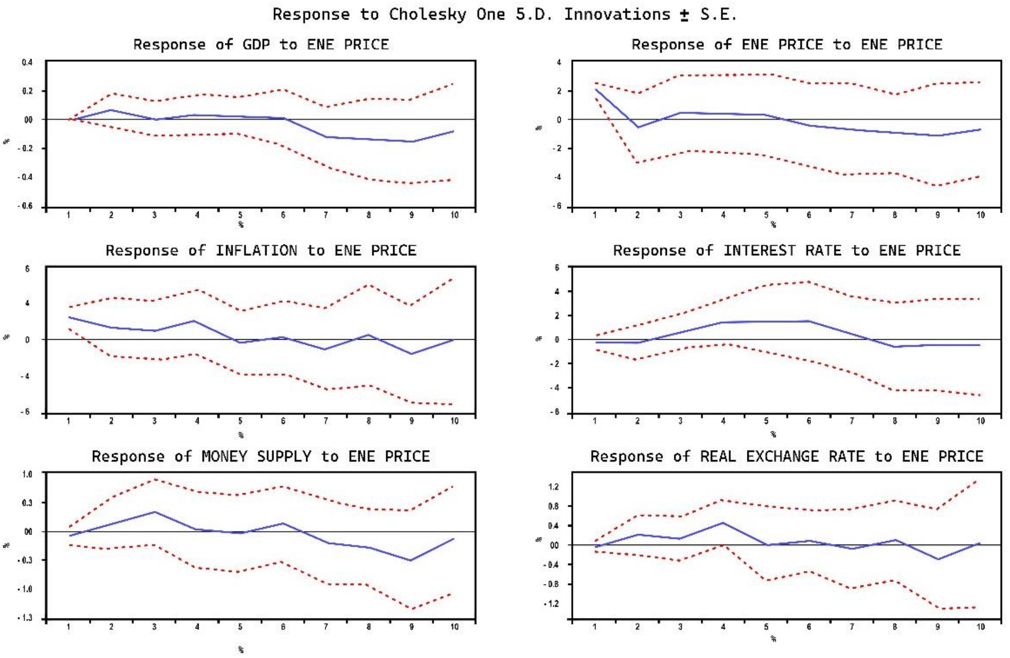


Figure 3. IRF to EPS (VAR IRF with intercept using annual data for 1980–2022).

6.1. Inflation Rate Shock

The inflation rate harms GDP and EP. To its shock, the IRF is optimistic. Because of the theory, there is a constructive association between inflation and MS, as shown in this graph in Figure 4. The reaction of the money supply to the inflation rate is optimal. GDP and EPS responses harm the money supply, whereas interest rates, money supply, exchange rate, and shocks positively affect the money supply. There is a negative correlation between GDP and INF in SACs.

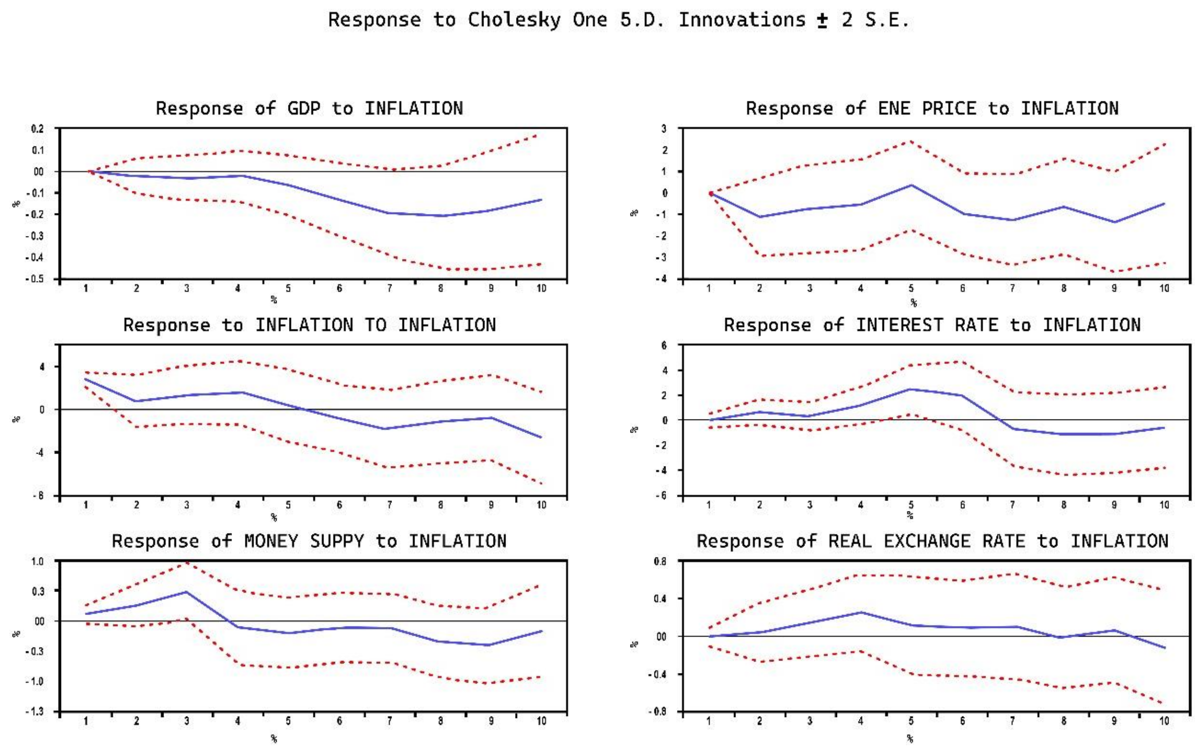


Figure 4. IRF to inflation rate (VAR IRF with intercept using annual data for 1980–2022).

6.2. MS Shocks Effect

The GDP's response to the money supply is negative, despite producing a positive response in its shock. The impact of other variables on money supply remains persistently positive over the entire forecast horizon, with volatility and responsiveness around equilibrium, as shown in Figure 5. The impact of money supply and interest rates does not die out over the entire forecast horizon for the United States GDP. The effect of money supply and exchange rate shocks remains persistently positive over the forecast horizon. EP cause a negative response in the money supply in the short run but not in the long run, whereas shocks to the interest rate, inflation rate, money supply, and exchange rate cause a positive response.

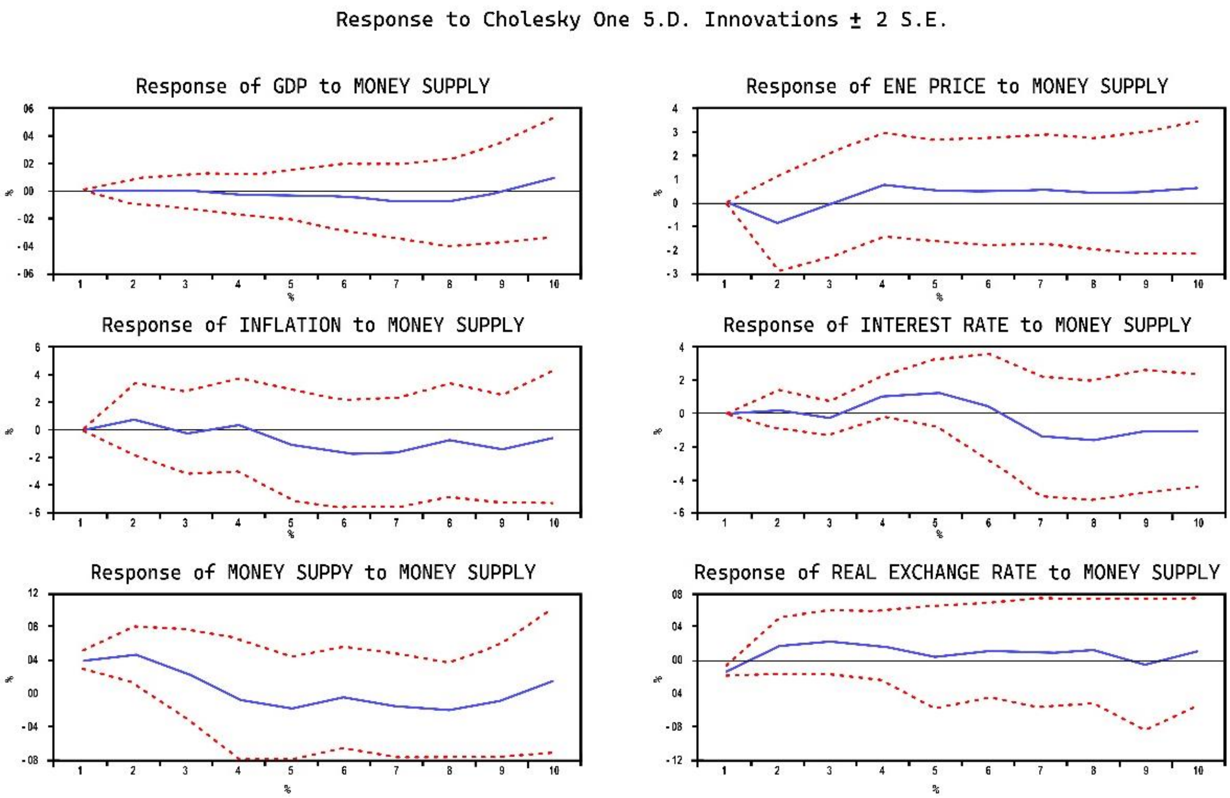


Figure 5. IRF to money supply (VAR IRF with intercept using annual data for 1980–2022).

6.3. Influence of EXP Shocks

This graph shows that the impact of GDP shocks on the exchange rate remains persistently positive over the entire forecast horizon and that GDP shocks produce a stable response in EXP over the whole forecast horizon. The spontaneous movements in the inflation rate show that the variable's behaviour has a negative impact at first, but it gradually provides a stable response in EXP, and it remains volatile around its origin, not in the short run but in the long run, which is consistent with the findings. The response of the energy price to the exchange rate is positive over the entire forecast horizon, EP and exchange rates lower the overall performance of the GDP. The impact of the money supply and shock is responsive around an equilibrium. Figure 6 depicts the response of the impulse for GDP to shocks in the exchange rate over the future forecast horizon. Figure 6 shows that at the early stage, the behaviour of the inflation rate has a negative impact, but gradually, it provides a stable response in the exchange rate, and it remains volatile around its origin, not in the short run but in the long run, which is consistent with the findings.

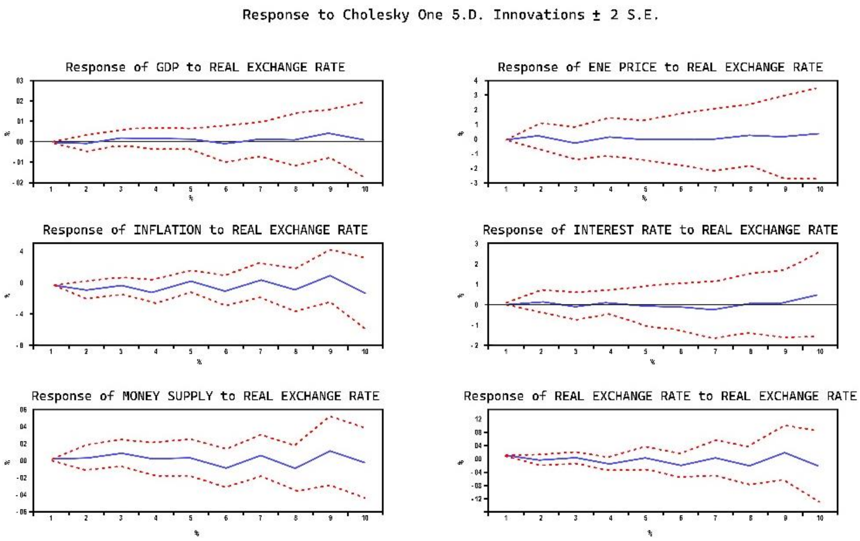


Figure 6. IRF to RER (VAR IRF with intercept using annual data for 1980–2022).

6.4. Impact of GDP Shocks

Figure 7 generalizes the impulse response function to one SD shock for the changes in GDP. It is noted that the horizontal axis, at the same time, explains the dependent level of the variable to the independent variables for this study. A positive GDP response to a shock converges to equilibrium and remains stable. In response to a shock to GDP, the EP increases initially after the 5th period but then becomes stable, while GDP shows a positive reaction to its shock. With GDP, inflation creates a negative impact at the early stage, but in the third period it generates a positive response, while the interest rate response is toward GDP. It shows a positive reaction and remains around equilibrium; for some time, from the 5th to the 6th, it has a negative response, but again it moves upward. In this graph, the money supply responds negatively at the initial level, but in the second period it generates a positive response and volatility around the equilibrium. This is contrary to the harmful impact of oil prices on GDP growth.

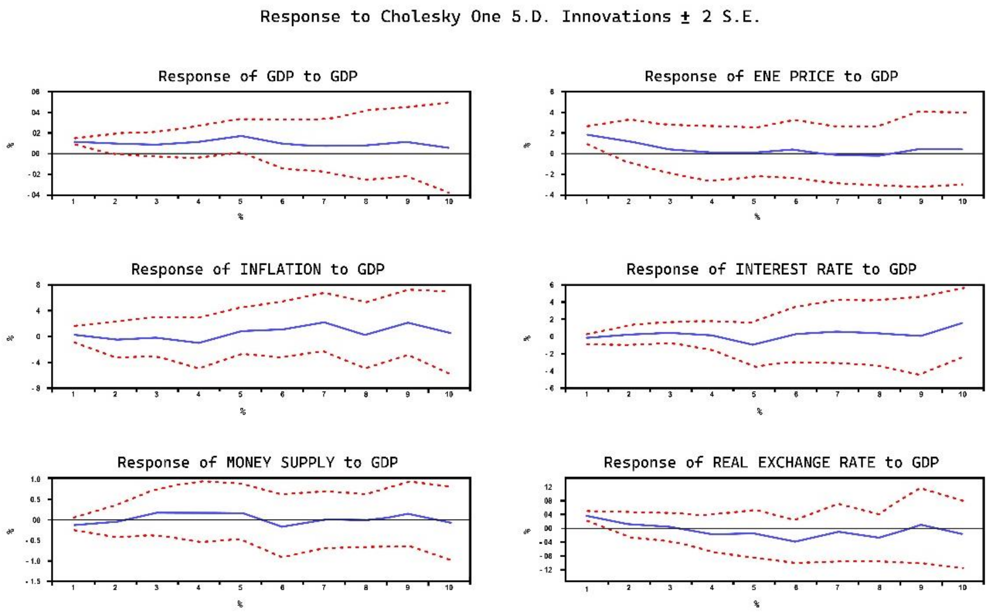


Figure 7. IRF to GDP (VAR IRF with intercept using annual data for 1980–2022).

6.5. Effect of Interest Rate Shocks

The GDP shocks produce a stable response in the interest rate over the entire forecast horizon. This lack of interest rate responsiveness to GDP shocks indicates a lack of responsiveness to investment expenditures translated into new investments. It is also found in [30] that the Australian economy faced problems with capacity utilization of the existing manufacturing units and mismatched demand for consumer goods. However, the economies of SACs have different issues: the energy crisis, lower capital and labour productivity levels, and underdeveloped factor markets. A GDP shock causes an adverse reaction in interest rates, which adjusts immediately after its impact but remains volatile over the forecast horizon around the equilibrium. The inflation rate generates a negative response in the interest rate and produces shocks that are also volatile over the forecast horizon, and for the rest of the shocks, the interest rate remains responsive, volatile, and around equilibrium, as in Figure 8.

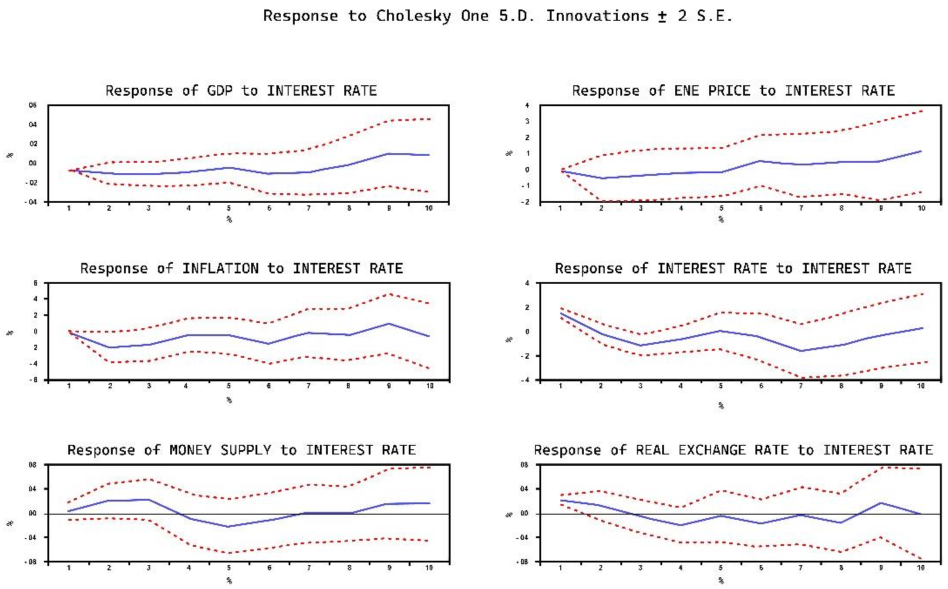


Figure 8. VAR impulse response to interest rate (VAR IRF with intercept using annual data for 1980–2022).

7. Conclusions

The study estimated the relationship between GDP (per capita), energy prices, interest rate, real effective exchange rate, money supply, and inflation that has critical macroeconomic implications not only in terms of the performance of the economy but also in shaping the future growth patterns of developing GDP such as SACs. This study concludes that the VAR analysis revealed that EPS and exchange rates significantly impact GDP performance, making this analysis relevant to understanding growth behaviour over the future time horizon. Unanticipated movements in the exchange rate and EP depress the overall economy, and the persistence of this impact can lead to a recessionary effect on the GDP of SACs. The forecasted impact of these variables does not seem to die out in the short run, making it imperative for policy initiatives to control the unanticipated volatility and movements in the exchange rate and EP.

Furthermore, the analysis found that sustainable EPS not only adversely affects the economy's (GDP) performance but also causes an appreciation in the exchange rate that remains persistent over the long term. It has numerous implications for the (GDP) economy, not only in terms of trade (both domestic and foreign) but also for monetary management by the central bank. On the other hand, the exchange rate shocks do not have a lasting effect on the economy's performance and inflation.

Our review suggests that empirical research on the EPS has been relatively limited in scope and yielded a small number of consistent findings and that many aspects of this developmental association remain unexplored, as my best search suggests. This study faced problems related to data availability, as quarterly and monthly data were unavailable for each variable.

8. Future Research Directions

Thus, EPS presents tremendous opportunities for future experimental research. The implications of the infrequent data would be significant. So, the different sets of variables can be used to analyse the model with a monthly or quarterly frequency of data.

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