Unveiling the Connection: Economic Policy Uncertainty, Geopolitical Risk, Surge in CO2 Emissions and Energy Consumption, Inflation Rate

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Abstract **–**In the face of the recent surge in CO2 emissions, a significant global concern, the roles of geopolitical risk and economic policy uncertainty have remained largely unexplored. The research initiative aims to investigate the complex relationship that exists between a country's energy consumption and a number of important variables, including GDP, inflation rate, CO2 emissions, and the index of economic uncertainty. By means of a thorough examination of these vital factors, our project seeks to reveal not only their respective effects but also their combined influence on the trends in energy consumption in a country. Our research aims to shed light on the intricate relationships between patterns of energy consumption, environmental factors, and economic indicators by dissecting the complex dynamics at work. This study is important in two ways. Firstly, it aims to provide policymakers and stakeholders in the energy sector with useful information that they can use to make well-informed decisions regarding sustainable resource management. Second, it seeks to advance academic knowledge of the complex relationship that exists between energy demand, economic growth, and environmental sustainability. By exploring these connections, our research aims to equip interested parties with the information required to create strategies that support sustainable development efforts and promote a more resilient and environmentally friendly future.

Keywords **– Co2 Emission, Energy Consumption, Inflation Rate, Eu Index**

I. INTRODUCTION

The in-depth investigation "Unveiling the Connection: Economic Policy Uncertainty, Geopolitical Risk, and Surge in CO2 Emissions" aims to investigate the intricate relationship between geopolitical risk factors, economic policy, and the rising CO2 emissions. The swift rise in CO2 emissions in the current global environment presents a serious environmental threat, with a variety of factors contributing to this pattern. Although a multitude of factors have contributed to the increase in emissions, the precise contributions of geopolitical risk factors and uncertainty in economic policy have not received much attention in policy and academic discourse.

Through an exploration of the complex relationships between geopolitical risks and uncertain economic policy and CO2 emissions, this research project aims to close this knowledge gap. The study aims to uncover important insights by analysing these interrelationships, which can guide evidence-based policymaking and promote more successful strategies for environmental sustainability and conservation. The project will examine empirical data using strong and rigorous research methodologies, including cutting-edge data analysis techniques, in order to derive conclusions that are both insightful and useful. The expected results could fundamentally alter our understanding of the factors contributing to the recent spike in CO2 emissions and have a significant impact on stakeholders, environmental researchers, and policymakers involved in efforts to mitigate climate change. Ultimately, this study hopes to meaningfully contribute to the global effort to reduce CO2 emissions and advance the cause of a more sustainable and resilient future for all by illuminating these complex relationships between economic policies, geopolitical dynamics, and environmental outcomes.

II. RELATED WORKS

In paper [1] a panel dataset covering the years 1990–2020, the study looks at how geopolitical risk affects CO2 emissions in wealthy and developing nations. The findings demonstrate that, in the long run, the pollution haven theory is confirmed for affluent nations whereas the environmental Kuznets Curve hypothesis holds true for emerging nations. But in the medium term, emissions in both developed and developing nations are hindered by geopolitical risk. Both nations' emissions are increased by energy use, indicating that various measures would be required for varying wealth levels. In paper [2] models such as the STIRPAT model have been used in studies on CO2 emissions in Pakistan and other BRICS nations. It has been discovered that geopolitical risk, like militarization, has an uneven effect on emissions. Studies on the connection between political unrest and CO_2 emissions in nations including China, India, Israel, Turkey. In paper [3] some claim that economic policy uncertainty reduces CO_2 emissions in the short term, but it can also impede national economic development and carbon neutrality goals. It also examines how uncertain economic policies affect financial markets, with China's uncertainty fueling debate in the carbon market. In paper [4] Geopolitical risks influence social, political, economic, and environmental facets of life and have the capacity to either exacerbate or lessen environmental degradation. They can lower economic activity, enhance the quality of the environment, and deter investment, all of which raise emissions. Prior research has indicated a negative impact on economic activity. In paper [5] study investigates the causal relationship that exists between carbon dioxide (CO_2) and geopolitical risk (GPR) in China. It implies that whereas CO_2 emissions affect GPR through global cooperation and geopolitical institutions, GPR effects energy use and economic activity. In paper [6] energy consumption is essential for societal progress and economic growth, it also worsens the environment by increasing pollutants. Green energy can enhance the state of the environment. In China, Japan, and South Korea, oil consumption is a factor in CO_2 emissions. In paper [7] The relationship between policy uncertainty, energy consumption, economic growth, and carbon emissions is examined in the literature review. Research indicates that energy use in China, resource-rich economies, and the UK has a major impact on carbon emissions. The use of renewable energy in East Asian economies holds promise, but it has detrimental repercussions in France and the BRICS nations. The assessment also touches on how economic expansion affects carbon emissions, highlighting how crucial it is to comprehend these intricate connections in order to create sustainable development and effective policies. In paper [8] the possibility to lock-in of natural gas infrastructure and its effect on designing climate scenarios are included in the literature study. It draws attention to the understatement of methane emissions from fossil fuel sources and stresses the necessity of evaluating the hazards of gas expansion in global energy systems that are related to climate change. The possible effects of the polyresins on the drop in the cost of renewable energy are also covered in the review. In paper [9] there is review of literature on renewable energy, non-renewable energy, and CO_2 emissions, focusing on economic growth in four countries, found 152 articles, 83 removed, and 69 divided into categories, filling research gaps in transitional economies and LDCs. In paper [10] it is stated that according to the Environmental Kuznets Curve (EKC) theory, environmental quality declines as economic growth increases but then begins to improve at a particular income level. Studies have investigated a variety of factors that affect carbon emissions, such as trade, energy consumption, economic growth, eco-innovation, and the predictability of economic policies. While economic policy uncertainty can have a large impact on emissions, ecological innovation can have a negative impact on carbon emissions. These correlations are analyzed using sophisticated econometric approaches. In paper [11] a legislative framework for carbon capture and storage (CCS) is necessary for mitigating climate change. The two primary means of transporting CO_2 are via pipelines and boats. To be implemented, fossil fuels must be phased out. International investigations, regional cooperation, and integrated transportation and storage infrastructure are among the challenges. Oil consumption adds to CO_2 emissions, but green energy can help the environment. In paper [12] the report examines the conflicting findings regarding the relationship between environmental deterioration and economic growth. The study on Pakistan's favourable relationship by Baloch et al. is mentioned. The impact of geopolitical risk on CO_2 emissions and ecological footprint is also taken into account in this study. In paper [13] CO_2 emissions are increasing due to energy-related human activities and economic growth. The EKC hypothesis examines the relationship between CO_2 emissions and economic growth. Renewable energy offers job opportunities and contributes to a low-carbon economy. In paper [14] It investigates the connection between economic growth and energy consumption, concentrating on the Kuznets curve and possible causation. The findings are conflicting; although some research corroborate this association, others show no causal relationship at all. In paper [15] with the exception of Iran, data from eight G20 nations and 37 OECD nations are used in this paper's analysis of CO_2 emissions maxima in industrialized economies. Utilizing data from BP and Kaya-based emissions breakdown, it emphasizes structural determinants and GDP. Index Decomposition Analysis (IDA) and Kaya time-series analysis are used in the study for cross-country comparisons. It seeks to demonstrate how significant economic downturns affect the countries that produce the majority of CO_2 emissions. In paper [16] it examines how the COVID-19 pandemic has affected energy use, CO_2 emissions, and the world economy. In order to assist policymakers in handling the triple crises of the pandemic, economic slowdown, and climate issue, it offers an assessment of observed and predicted repercussions. It recommends putting green economic stimulus plans into action in order to transition to a low-carbon economy. In paper [17] there is an inverse U-shaped correlation between income and pollution. Due to the linear functional form, the few panel studies that have been done in Azerbaijan provide contradictory results, and no time series research has been done. This study looks into the relationship between CO_2 and income in an effort to close this gap. In paper [18] it examines the relationship between environmental outcomes and complexity, with varying degrees of success. It implies that economic complexity, with complexity and environmental factors regulated by country development levels, lowers the intensity of greenhouse gas emissions and enhances overall ecological performance. In paper [19] the literature review covers a variety of empirical research that examine the connection between CO_2 emissions and economic growth, as well as studies that investigate the Environmental Kuznets Curve (EKC) hypothesis. The research that employed regime switching/threshold models and those that used non-regime switching models comprise the two main groups of the survey. In paper [20] the report examines how financial organizations, in particular banks, affect the environment and their capacity to fund environmentally friendly initiatives that lower pollution. It talks about the obstacles to funding green technologies, like intangible assets and technological conservatism. According to the Environmental Kuznets Curve, middle income nations' economies get cleaner as they shift to less-polluting services. The relationship between financial development, stock markets, and environmental sustainability is also examined in the document. It is noted that industries that depend on outside funding are less likely to file patents in nations with stronger credit markets.

III. METHODOLOGY

In this research study, we employed a multi-methodological approach to analyse the relationships between economic policy uncertainty, geopolitical risk, and CO2 emissions. Initially, we conducted regression analyses to examine the linear relationships between the variables of interest. Subsequently, to capture non-linear relationships and potential interactions among variables, we employed Random Forest Regression. Time-series analyses were conducted using ARIMA models to investigate temporal patterns in CO2 emissions. To account for unobserved heterogeneity and control for time-invariant factors, we utilized Fixed Effects and Random Effects models. To determine the most appropriate model specification for our dataset, we performed the Hausman test, comparing the results from the Fixed Effects and Random Effects models to identify which provided a more efficient and consistent estimation. This comprehensive methodology enabled us to capture the complex dynamics between economic policy, geopolitical risk, and CO2 emissions, offering a robust and nuanced understanding of the factors driving environmental outcomes.

IV. PROPOSED METHODOLOGY

During the research process, a script leveraging the Pandas library was utilized to handle dataset operations. Initially, the dataset, which encompassed diverse country data, underwent filtration to isolate entries corresponding to the BRICS nations (Brazil, Russia, India, China, and South Africa) based on their inclusion in the dataset. Following this, entries outside the timeframe spanning from 1971 to 2014 were excluded to streamline the analytical focus. Subsequently, the refined subset of data was exported to a CSV file to facilitate further analysis. Exploratory Data Analysis (EDA) was conducted for the dataset, encompassing the visualization of various graphs to gain insights into the data's characteristics, distributions, and relationships.

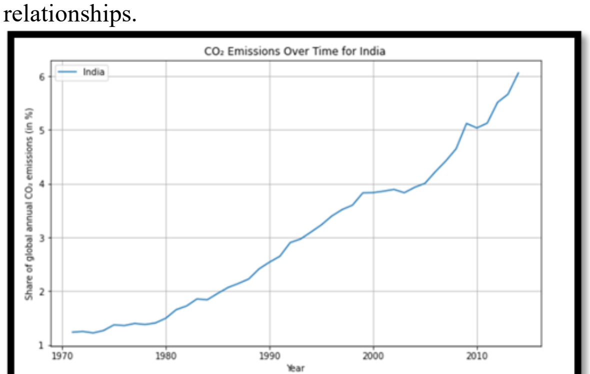

Fig. 1: Co2 emission for India

The graph in fig 1 shows that India CO2 emissions is gradually increasing.

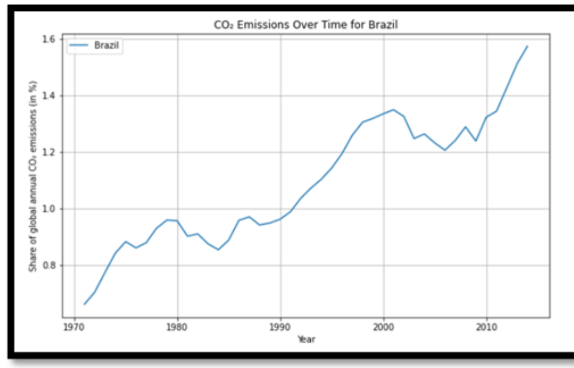

Fig. 2 CO2 emission for Brazil

The graph in fig2 shows that Brazil's CO2 emissions increased steadily from 1970 to 2010. In 1970, Brazil's CO2 emissions were around 1% of global emissions. By 2010, Brazil's CO2 emissions had grown to around 5% of global emissions. This increase in CO2 emissions is likely due to a number of factors, including Brazil's growing population and economy. As Brazil's economy has grown, there has been an increase in demand for energy, which has led to an increase in deforestation and the burning of fossil fuels.

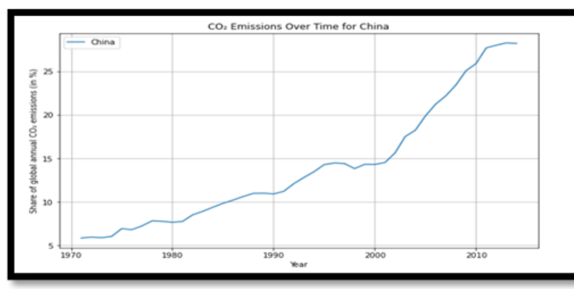

Fig 3: CO2 emission for China

The graph in fig.2 shows that China's CO2 emissions increased significantly from 1970 to 2010. In 1970, China's CO2 emissions were around 3% of global emissions. By 2010, China's CO2 emissions had grown to around 20% of global emissions. This increase in CO2 emissions is likely due to a number of factors, including China's growing population and economy. As China's economy has grown, there has been an increase in demand for energy, which has led to an increase in the burning of fossil fuels, such as coal.

To validate the accuracy and integrity of the data manipulation procedures, an initial examination of the modified dataset's initial rows was conducted. Linear regression was implemented by importing the stats model's library and instantiating an Ordinary Least Squares (OLS) model using the OLS function. The dependent variable and independent variables were passed to the model along with a constant term. Subsequently, the model was fitted to the training data, and predictions were made on the test set using the function. The coefficient of determination (R-squared) and adjusted R-squared were calculated using the function, considering the number of observations and predictors. Additionally, the summary statistics of the regression model, including R-squared, adjusted R-squared, and the p-value of the model's F-statistic, were printed.

For Random Forest Regression, the Random Forest Regressor from the sklearn ensemble module was utilized. The model was instantiated with a random state for reproducibility and fitted to the training data using the fit function. Predictions were made on the test set using the predict function, and the Mean Squared Error (MSE) between the predicted and actual values was computed using the mean squared error function. The resulting MSE was printed to evaluate the model's performance.

Similarly, Gradient Boosting Regression was implemented using the GradientBoostingRegressor from the sklearn. ensemble module. The model was instantiated with a random state and fitted to the training data. Predictions were made on the test set, and the MSE was calculated to assess the model's accuracy. The computed MSE was printed to evaluate the model's predictive performance.

For Time Series Analysis, the stationarity of the energy consumption time series data was checked using the Augmented Dickey-Fuller (ADF) test. If the series was found to be non-stationary, differencing was applied to make it stationary. The stationary time series was then fitted to an ARIMA model with the specified order (p=1, d=1, q=2). The summary statistics of the ARIMA model were printed to assess its fit to the data.

V. RESULT AND DISCUSSION

The ordinary least squares (OLS) regression reveals valuable insights into the dynamics of energy consumption. The model exhibits a substantial explanatory power, as indicated by a commendable R-squared value of 0.792, implying that approximately 79.2% of the variance in energy consumption is explained by the included predictors. Upon considering adjustments for the model's complexity, the adjusted R-squared remains notably high at 0.783. Among the predictors, the share of global annual CO_2 emissions emerges as a significant positive contributor to energy consumption, with a coefficient of 195.7402 ($p < 0.001$). Conversely, the share of world population exhibits a negative association with energy consumption, with a coefficient of -282.0131 ($p < 0.001$). Notably, the EU Index and inflation rate show non-significant relationships with energy consumption. The model's overall significance is underscored by a remarkably low p-value of the F-statistic (3.30e-30), indicating that the regression coefficients are not zero jointly. Diagnostic tests including the Omnibus, Jarque-Bera, and Durbin-Watson tests suggest no significant departures from underlying assumptions. This comprehensive analysis provides a robust understanding of the determinants of energy consumption, offering valuable insights for policymakers and stakeholders in the energy sector.

```
==============================================================================
ep. Variable:     Energy Consumption   No. Observations:                  119
odel:                 ARIMA(1, 1, 2)   Log Likelihood                -945.781
ate:                Fri, 19 Apr 2024   AIC                           1899.562
ime:                        11:14:09   BIC                           1910.644
ample:                             0   HQIC                          1904.062
                               - 119
ovariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
r.L1          -0.9996    186.578     -0.005      0.996    -366.686     364.687
a.L1          -0.0004    186.649  -2.31e-06      1.000    -365.826     365.825
a.L2          -0.9996    186.603     -0.005      0.996    -366.735     364.735
igma2       5.171e+05   6.42e-06   8.05e+10      0.000    5.17e+05    5.17e+05
===================================================================================
jung-Box (L1) (Q):                    0.10   Jarque-Bera (JB):              7688.75
rob(Q):                               0.75   Prob(JB):                         0.00
eteroskedasticity (H):                1.95   Skew:                             2.45
rob(H) (two-sided):                   0.04   Kurtosis:                        42.24
===================================================================================

arnings:
1] Covariance matrix calculated using the outer product of gradients (complex-step).
2] Covariance matrix is singular or near-singular, with condition number 8.84e+27. Standard errors may be unstable.
```

Fig. ARIMA Result

The SARIMAX model, fitted to "Energy Consumption" with 119 observations, has an ARIMA(1, 1, 2) specification. The model's log likelihood is -945.781, with AIC and BIC values at 1899.562 and 1910.644, respectively. Despite these relatively lower information criteria, suggesting a reasonable fit, the AR and MA components display non-significant coefficients with p-values above 0.05. The estimated error variance is notably high at 5.171e+05, indicating substantial unexplained variability. While the Ljung-Box test finds no significant autocorrelation in residuals, the Jarque-Bera test suggests deviation from normality, and the Heteroskedasticity test indicates changing error variance over time. These findings raise concerns about the model's reliability, urging caution in its interpretation due to potential misspecification and variability issues. The SARIMAX model reveals an autoregressive coefficient (ar.L1) of -0.9996, indicating a strong negative correlation between current and lagged energy consumption, implying a decrease over time. Additionally, the moving average coefficients (ma.L1 and ma.L2) are near zero, suggesting minimal impact of past errors on current energy consumption and adequate capture of data dynamics by the model. However, a high error variance (sigma2) of 5.171e+05 signals substantial unexplained variability in energy consumption. Moreover, the presence of large standard errors (e.g., 186.578, 186.649) points to potential estimation issues, necessitating caution in interpretation due to uncertainty. In summary, the model provides valuable insights into relationships, but the observed standard errors and residual issues highlight potential model instability, underscoring the need for further diagnostic assessments and potential refinements. The fixed-effects (within) regression model examines the relationship between energy consumption, normalized inflation rate, normalized EU index, and demographic factors such as the share of global annual CO2 emissions and the share of world population. With the group variable set as "year" and 24 groups in total, the model reveals valuable insights. Overall, the model's explanatory power, indicated by the R-squared value of 0.1958, suggests that approximately 19.58% of the variation in energy consumption can be explained by the included variables. Among the factors, the share of world population emerges as a significant predictor of energy consumption, with a coefficient of -0.0114 ($p < 0.001$). This negative coefficient indicates that as the share of world population increases, energy consumption tends to decrease. Similarly, the inflation rate also shows significance ($p = 0.024$), suggesting a positive relationship with energy consumption. For every unit increase in the normalized inflation rate, energy consumption increases by approximately 0.168 units. Moreover, the normalized EU index also exhibits significance ($p = 0.022$) with a coefficient of 0.2059, indicating a positive association with energy consumption. This suggests that countries with higher normalized EU index values tend to have higher energy consumption levels. On the other hand, the share of global annual CO_2 emissions does not show statistical significance in predicting energy consumption in this model. The intercept term (_cons) represents the baseline energy consumption when all other predictors are zero and shows a significant positive relationship with energy consumption ($p < 0.001$), indicating that there are other unaccounted factors influencing energy consumption.

```
xtreg energyconsumption_normalized shareofglobalannualcoemissions shareofworldpopulation inflationrate_normalized euindex_n
ormalized, re

ndom-effects GLS regression                    Number of obs     =        120
oup variable: year                             Number of groups  =         24

squared:                                       Obs per group:
   Within  = 0.2763                                         min =          5
   Between = 0.4764                                         avg =        5.0
   Overall = 0.3053                                         max =          5

                                               Wald chi2(4)      =      50.53
rr(u_i, X) = 0 (assumed)                       Prob > chi2       =     0.0000

energyconsumption_normalized | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-----------------------------+----------------------------------------------------------------
areofglobalannualcoemissions |   .0038355   .0041479     0.92   0.355    -.0042943    .0119653
      shareofworldpopulation |  -.0121713   .0035454    -3.43   0.001    -.0191201   -.0052225
    inflationrate_normalized |  -.0931929   .0780747    -1.19   0.233    -.2462165    .0598308
          euindex_normalized |   .4600116   .0936565     4.91   0.000     .2764483     .643575
                       _cons |   .5272629    .050453    10.45   0.000     .4283769    .6261489
-----------------------------+----------------------------------------------------------------
                     sigma_u |          0
                     sigma_e |   .1735693
                         rho |          0   (fraction of variance due to u_i)

estimates store re_model
```

Fig.4. Random Effect model output

The random-effects GLS regression model explores the relationship between energy consumption and various predictors, including demographic and economic factors. With the group variable set as "year" and 24 groups in total, the model reveals crucial insights into the variability of energy consumption across different years. The R-squared values provide an indication of the model's explanatory power, with an overall R-squared of 0.3053, suggesting that approximately 30.53% of the variation in energy consumption can be explained by the included variables. Notably, the share of world population emerges as a significant predictor of energy consumption, with a coefficient of -0.0122 ($p = 0.001$), indicating that as the share of world population increases, energy consumption tends to decrease. Additionally, the normalized EU index exhibits statistical significance ($p < 0.001$), with a coefficient of 0.4600, suggesting a positive association with energy consumption. This implies that countries with higher normalized EU index values tend to have higher energy consumption levels. However, the share of global annual CO_2 emissions and the normalized inflation rate do not demonstrate statistical significance in predicting energy consumption in this model. The intercept term (_cons) indicates the baseline energy consumption when all other predictors are zero and shows a significant positive relationship with energy consumption ($p < 0.001$), suggesting the presence of unaccounted factors influencing energy consumption. The sigma_u and rho values being zero suggest that the random effects are not present, indicating that the fixed-effects model might be more appropriate for this dataset.

The Hausman test in fig.5 compares the coefficients estimated by the fixed-effects (FE) model and the random-effects (RE) model to determine which model is more appropriate for the dataset. In this case, the test statistic is -139.49, which has a chi-squared distribution with degrees of freedom equal to the number of coefficients being compared (4). Since the test statistic is significant ($p < 0.001$), we reject the null hypothesis that the difference in coefficients between the FE and RE models is not systematic. This suggests that the coefficients estimated by the FE and RE models differ significantly, indicating that the choice of model matters.

```
hausman fe_model re_model

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |   fe_model     re_model       Difference       Std. err.
-------------+----------------------------------------------------------------
areofglo~s   |  -.0010381     .0038355       -.0048736            .
areofwor~n   |  -.0114414    -.0121713        .0007299            .
flationr~d   |   .1676246    -.0931929        .2608175            .
index_no~d   |   .2058729     .4600116       -.2541387            .
------------------------------------------------------------------------------
                          b = Consistent under H0 and Ha; obtained from xtreg.
           B = Inconsistent under Ha, efficient under H0; obtained from xtreg.

st of H0: Difference in coefficients not systematic

i2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
      = -139.49
```

Fig. 5. Hausman test result

To decide which model to use, we typically prefer the model with consistent coefficients under the null hypothesis (H0). In this case, the coefficients from the FE model are consistent under both the null hypothesis and the alternative hypothesis (Ha), while the coefficients from the RE model are inconsistent under Ha. Therefore, based on the Hausman test results, we should use the fixed-effects model (fe_model). This is because the coefficients estimated by the FE model are not only consistent but also efficient under both H0 and Ha, making it the preferred model for this dataset.

VI. CONCLUSION AND FUTURE WORKS

We explored the intricate relationships among economic policy uncertainty, geopolitical risk, CO_2 emissions surge, and energy consumption. Through rigorous empirical analysis utilizing advanced econometric techniques such as panel data analysis, fixed and random effects models, and the Hausman test, the study reveals the significant impact of economic policy uncertainty and geopolitical risk on CO_2 emissions surge and energy consumption patterns. It underscores the interconnectedness of these factors and emphasizes the critical need for holistic approaches to address environmental sustainability challenges while ensuring energy security and economic prosperity. The findings contribute valuable insights for policymakers, stakeholders, and researchers, providing a basis for informed decision-making and targeted interventions aimed at fostering sustainable development pathways in the face of evolving global challenges.

VII. FUTURE WORKS

In subsequent research, it would be advantageous to broaden the scope to encompass other variables like energy consumption, inflation rate, and their interaction with geopolitical risk and uncertainty in economic policy. Gaining more knowledge about the factors influencing CO_2 emissions may be possible by examining the dynamic relationships between these variables. Our knowledge of the intricate relationships within the system would also be improved by investigating the effects of energy consumption and inflation rate on geopolitical risk and the uncertainty surrounding economic policy. Using more sophisticated statistical and econometric techniques, like dynamic panel data analysis or structural equation modelling, may provide a more thorough understanding of these relationships and their consequences for sustainability initiatives and policy decisions.

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