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# The influence of renewable energy and economic freedom aspects on ecological sustainability in the G7 countries

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## Abstract

With the exemption of Canada, the G-7 countries have largely flourished at the detriment of their ecological sustainability bearing in mind that these countries' have remained ecologically deficit for several decades. Given the potential effect of environmental degradation associated with the trend of ecological deficit of these countries, this study attempts to understand the contribution of renewable energy dimensions through the measure of renewable energy efficiency and renewable energy use alongside evaluating the role of the four main aspects of economic freedom. By using empirical tools, the findings revealed that renewable energy aspects contribute to environmental sustainability among the countries through a significant mitigation of their ecological footprint. Importantly, the aspects of economic freedom, that is, government size, legal system and property rights, freedom to trade internationally, and regulation hampers environmental sustainability by increasing the countries ecological footprint. The elasticity of impact of this dimension of economic freedom is in the range of 0.19–0.21 at 1% statistically significant level. However, population of these countries does not show a detrimental effect, rather the finding revealed that population improves environmental quality by a statistically significant degree. Given these revelations, there are deducible policy take home from this study.

**KEYWORDS**

ecological footprint, economic freedom, G-7 countries, renewable energy, sustainable development and environment

## 1 | INTRODUCTION

One of the salient and protracted issues about the G-7 countries is the sustainability of the countries' natural capital considering that all the member countries (except Canada) are ecologically deficit (Global footprint network, 2019). The considerable danger to environmental quality posed by climate change has remained one of the most significant obstacles to long-term growth, even though a few G-20 and G-7 nations have sustained economic growth over the previous decade. Considering that the G-7 countries constitute over 60% of the world's net global wealth as a result of vast economic activities, pollutant emissions from fossil fuels, coal, and traditional cooking fuels such as firewood are becoming the most significant source of pollutants, resulting in major environmental damage (Alola et al., 2022). The G-7 nations account for roughly 30% of the world's energy consumption and 25% of its $CO_2$ emissions, respectively (Ahmad et al., 2021). The G7 nations also significantly rely on imported and domestic non-renewable energy sources for their energy use. Around 96%, 84%, and 64% of Japan's, Italy's, and Germany's entire primary energy supply, respectively, is imported (EIA, 2022). These percentages thereby emphasize the problem of the G7 countries' dependence on dirty fuels. According to Beck and Mahony (2018), greenhouse gas emissions must be cut by 45% by 2030 compared to 2010 levels, with net-zero status achieved around 2050 to meet the 1.5°C target. Furthermore, because environmental deterioration is strongly linked to economic development, all countries' primary aim, especially advanced countries in sustainable development, is to leave a habitual environment for future generations while exhibiting an inclusive growth performance. All countries follow specific policies frequently discussed by leaders of various supranational organizations in the context of environmental degradation, so much so that, when the global situation of climate change is examined, it is suggested that, if current consumption patterns continue, another planet may be required soon.

With concrete attempts being made to avert future calamity, renewable Energy (REN) is increasingly being harnessed and used since it is an aspect of a sustainable environment, with efforts to mitigate environmental degradation globally. In a bid to reduce the effect of climate change, developed countries have increased efforts to switch to more efficient energy sources (Alola, Bekun, & Sarkodie, 2019). With REN investment exceeding 214 billion USD in 2013, it is promoted as a viable strategy to prevent climate change. As a result, REN usage has increased from 16% of total energy consumption in 2007 to 18% in 2016 (World Bank, 2017). Furthermore, this percentage will rise by 2022 as economies become more concerned about using cleaner energy and embracing the green economy (IEA, 2017). As a result, several of the world's largest fossil fuel consumers have implemented decarbonization policies to enable a smooth transition to low-carbon renewables (Ike et al., 2020; International Energy Agency, 2015; Iorember et al., 2021; Usman et al., 2020). However, in the 21st century, integration of economies is another contentious issue in the context of the energy market, especially in light of global economic freedom factors (Akadiri et al., 2021). By easing laws and opening their economies, all nations promote the international stock of assets and liabilities and foreign investment (Bilgili et al., 2020). For instance, financial globalization has risen over time in the G7 (Germany, Italy, France, Japan, Canada, United States, and United Kingdom) nations. The G7 countries' average financial globalization index rose from 52.01 in 1980 to 80.20 in 2016 (Ahmad et al., 2021). In this context, economic freedom factors will probably play a significant role in shaping the environmental qualities across the G7 countries considering that the situation has been established for the G-20 and other economies (Akadiri et al., 2021; Alola et al., 2022).

Although there are several attempts to investigate the effect of renewable energy and its aspects on environmental degradation for many cases across the globe, there is limited study of the contribution of economic freedom aspects. Some studies have found that REN reduces environmental deterioration, helps to conserve the environment, and promotes economic growth (Apergis et al., 2018; Balsalobre-Lorente et al., 2018; Emir & Bekun, 2019). Others have found that it has no discernible effect on environmental degradation (Frondel et al., 2010; Marques & Fuinhas, 2012). Therefore, as an objective, the current study investigates the influence of renewable energy and other dimensions of economic freedom on environmental sustainability in G-7 nations. The study employs ecological footprint as a proxy to quantify environmental sustainability to reach the intended outcome of investigating the drivers of ecological footprint in a two-model framework: The roles of GDP, population, and renewable energy aspects are examined through model 1. In model 2, the roles of the aspects of economic freedom alongside the renewable energy aspects are examined. In addition to GDP, population, the size of the government, and the measures of economic freedom such as property rights, freedom of international trade, and regulation, renewable energy use and renewable energy efficiency are included as explanatory variables. The degree of the relationship between these factors on the environment in the G-7 countries is still not fully understood. Nevertheless, environmental sustainability is pivotal to enhancing and conserving resources, leading to economic development.

This study makes a novel contribution to the current literature as the first study to examine how the aspects of economic freedom, that is, government size, legal system and property rights, freedom to trade internationally, and regulation in the G-7 countries, affect the ecological footprint vis-à-vis environmental sustainability. The EF is arguably the only indicator that appropriately compares socioeconomic—that is, government, business, and individual resource—demands to what the Earth can regenerate. Since the G-7 countries are vast economic weights that have maintained increased production of goods and services over the years, the adoption of EF becomes appropriate since it is a more comprehensive assessment of environmental quality that considers the entire biosphere. In accomplishing the objective of the study, empirical approaches that account for spillover of country-specific effects alongside the fixed and random effect models that deal with endogeneity problems were also employed in the study.

The remainder of this article is organized as follows: the literature review is presented in the "review of related studies" heading while the "Data information and priori estimations" heading is reserved for the description of the dataset. The results from the empirical examination and the discussion of the results come under the heading "results and discussion." Finally, the section "conclusion and policy implication" is reserved for the summarized information about the study and the recommended policy relevance.

## 2 | REVIEW OF RELATED STUDIES

### 2.1 | Theoretical framework

Holdren and Ehrlich (1974) primarily modeled environmental impact (I) in the framework that population (P), affluence (A), and technology advancement (T) are the key drivers. Following this mechanism, a major economic indicator, especially the gross domestic product, is assumed to exhibit a non-linear (such as a U- or inverted U-shaped) relationship with environmental degradation. In case of an inverted U-shaped relationship, that is, Environmental Kuznets Curve (EKC) hypothesis, a rise correlation between the economic and environmental degradation indicator ensues (Stern, 2004). Scale, composite, and technique have all been employed as observational methods for the EKC phenomena. Scale effects are the technical term for this transition. The composite effect refers to the transitional period from an industrial to a service-based economy. As a result of technological improvement and the updating of antiquated practices, pollution begins to reduce with continued economic expansion. This standpoint has led to the further conceptualization of the U-shaped relationship between economic output and environmental sustainability by incorporating additional indicators, such as urbanization, GDP, regulation, ICT, trade openness, tourism, technology, health, and agriculture (Alola et al., 2022; Asongu, 2018; Balsalobre-Lorente et al., 2022; Higón et al., 2017; Ozturk et al., 2016; Qin et al., 2021; Shahbaz et al., 2014).

## 2.2 | Empirical literature

Most studies on environmental degradation employ $CO_2$ emission as an indicator to study climate change. However, recent literature has emphasized the importance of the ecological footprint as an environmental sustainability indicator. For example, Destek and Sarkodie (2019) employed the ecological footprint instead of $CO_2$ as a proxy for environmental quality to examine the environmental Kuznets curve (EKC) hypothesis in a study that investigated the impact of environmental degradation on economic development in newly industrialized nations. By including other control variables like energy consumption and financial development, the study discovered an inverted U-shaped association between GDP and the ecological footprint for the case of 11 newly developed countries. As a result, the EKC hypothesis is validated. Similarly, in a previous investigation, Alola, Yalçiner, et al. (2019) used ecological footprints as an environmental indicator in an investigation that revealed that fertility, trade policy, energy utilization types, and economic growth all play a significant role in driving the ecological footprint of the European Union member countries.

Using both the two-step difference and system GMM estimations, Alola et al. (2022) investigated the economic freedom factors (legal system and property rights, sound money, international trade freedom, and regulatory efficiency) associated with the G-20 economies from sustainable development perspectives, that is, sustainable income and environmental sustainability. Surprisingly, the result, especially from the perspective of the economy, was not desirable because the economic factors were found to have a significant and positive impact on the ecological footprint. In another study, Nathaniel and Khan (2020), using a dataset for the time 1990–2016, studied the influence of renewable and non-renewable energy use, economic growth, trade and urbanization on environmental footprint for ASEAN countries. Their study shows the evidence that economic expansion, trade, and non-renewable energy usage had a significant impact on environmental degradation.

Moreover, Chapron et al. (2017) and Yamineva and Liu (2019) investigated the implication of environmental laws' legal boundaries. Specifically, the importance of the legal system in safeguarding environmental rules and implementing climate policy across borders was emphasized in the studies. Chapron et al. (2017) argued that when the legal system is strengthened, governments, as well as individual and corporate actors, are held accountable for environmental regulations. By using the Common Correlated Effects Mean Group (CCEMG), Alola et al. (2022) is another relevant study, which looked at the impact of socioeconomic and the rule of law (legal system) on environmental sustainability in a panel of Global South (low and medium income) nations from 1984 to 2014. The study discovered that the strength of the legal system in the Global South does not play a statistically significant role in reducing carbon emissions in the panel countries while socioeconomic factors are detrimental to environmental quality of the examined countries.

Empirically, there is no agreement on whether the government size enhances or degrades environmental quality. The environmental implications of government size can vary greatly between economies (Lan et al., 2022). Recently, Jain and Kaur (2022) found that countries with more EF-compliant institutions and policies experience faster economic growth, greater investment rates, higher income levels, faster poverty reduction, and better air quality. In a comprehensive study, Adewuyi (2016) collected data from 40 of the world's most polluted countries from 1990 to 2015 to examine the effects of government spending on $CO_2$ emissions. The data revealed that a 1% increase in government spending resulted in a 0.034% increase in $CO_2$ emissions over time. However, some authors found contracting results for a similar investigation. For instance, Chen (2022) investigated how $CO_2$ emissions in BRICS countries respond to government size and digitization changes. In the long run, the authors' empirical estimates using the ARDL technique demonstrate that government size leads to an increase in $CO_2$ emissions in Brazil, India, and China but negatively impacts Russia.

Adedoyin et al. (2021) examined the relationship between renewable energy, trade, income, and emissions for 27 European Union countries using data from 1990 to 2017. The long-run relationship between the variables was explored using second-generation panel model estimate techniques (AMG & CCEMG). Renewable energy has a significant and long-term negative influence on emissions. On the other hand, trade and income have a beneficial impact on emissions, although trade has an insignificant impact. Using data from the US economy from 1970 to 2015, Zafar et al. (2019) studied the effects of natural resources, human capital, and foreign direct investments on the ecological footprint in the context of energy consumption and economic growth. The study was implemented with the use of autoregressive distributed lag (ARDL). The result uncovered that economic growth and non-renewable energy consumption have a negative impact on the ecological footprint. However, natural resource utilization, human capital, and foreign direct investments positively impact EF. Xue et al. (2021) examined the effect of renewable energy use on ecological footprints in a sample of four South Asian countries. Furthermore, the result revealed that as renewable energy use increases, ecological footprints decrease. In this context, they draw attention to the importance of increasing economic growth by reducing fossil fuel

**TABLE 1** Description of variables

| Variable | Definition | Measurement | Source |
|---|---|---|---|
| EF | Ecological footprint | Global hectares | Global footprint network |
| GDPc | Gross domestic product per capita | Constant 2015 U.S. dollars | World Bank |
| REU | Renewable energy use | Tonnes of oil equivalent | OECD |
| POP | Population | In millions of people | |
| REF | Renewable energy efficiency coefficient | Numeric value | IEA |
| GS | Government size | Index | Fraser Institute |
| LSPR | Legal system and property rights | Index | Fraser Institute |
| FT | Freedom to trade internationally | Index | Fraser Institute |
| REG | Regulation | Index | Fraser Institute |

**TABLE 2** Descriptive statistics

| | EF | GDPc | REU | POP | REF | GS | LSPR | FT | REG |
|---|---|---|---|---|---|---|---|---|---|
| Mean | 7.737 | 38,881.48 | 35,961.63 | 1.04E+08 | 39.418 | 5.685 | 7.480 | 8.154 | 7.780 |
| Std. dev | 0.372 | 8343.74 | 37,535.55 | 86,011,531 | 26.938 | 0.836 | 0.756 | 0.483 | 0.818 |
| Skewness | 0.089 | −0.228 | 1.845 | 1.675 | 0.654 | −0.356 | −0.855 | 0.265 | −0.566 |
| Kurtosis | 1.940 | 2.681 | 5.395 | 4.353 | 2.041 | 2.771 | 3.154 | 2.584 | 2.413 |

dependency and restricting foreign investment inflows that pollute the environment in sustainable development. Therefore, this study provides new insight on factors that affect EF.

## 3 | DATA INFORMATION AND PRIORI ESTIMATIONS

This study explores the relationship among the selected variables with two different models. Based on the literature, we propose that renewable energy and economic aspects alongside the aspects of economic freedom will influence the ecological footprint in two separate models. This paper employs both a fixed effect model and random effect model to examine this relationship. Model I constructs the drivers of ecological footprint as a function of GDP per capita, renewable efficiency and population. Model II constructs the drivers of ecological footprint as a function of renewable energy use and the aspects of economic freedom, that is, government size, legal system property rights, freedom to trade internationally and regulation in G7 countries (Canada, France, Germany, Italy, Japan, United States, and United Kingdom) for the period covering 2000–2016. The data set used in the study is annual and was largely retrieved from the online database of Fraser Institute (2019), Global footprint network (2019), International Energy Agency (2019), OECD (Organisation for Economic Co-operation and Development) databas, and World Development Indicators of the World Bank (2017). Table 1 shows the variables used in this analysis with the implementation of the following models:

Simple panel model for the Model I is as follows:

$$EF_{it} = \gamma_0 + \gamma_1 GDPc_{it} + \gamma_1 REU_{it} + \gamma_2 POP_{it} + \mu_{it}.$$

Simple panel model for Model II is as follows:

$$EF_{it} = \gamma_0 + \gamma_1 GDPc_{it} + \gamma_1 REF_{it} + \gamma_3 GS_{it} + \gamma_4 LSPR_{it} + \gamma_5 FT_{it} + \gamma_6 REG_{it} + \mu_{it}.$$

The result of the summary statistics for the data set is presented in Table 2. The mean value of the population is the highest, while the government size has the lowest mean value. Similarly, the population's standard deviation is the highest, while the ecological footprint has the lowest. All the variables are positively skewed except for gross domestic product per capita, government size, legal system and property rights and regulation, which were negatively skewed. Likewise, kurtosis shows that renewable energy use and population have heavy/fat tails. The Jarque–Bera test also confirms that gross domestic product per capita, government size, and freedom to trade internationally have a normal distribution, while the remaining variables in this study were not normally distributed. Aside from the normality test, we employed a Q–Q plot to display the graphical distribution of the variables. The linear diagonal blue line depicts the normal distribution in the Q–Q plot. In contrast, the dotted line represents the departure from the normal distribution, as shown in Figures A1–A9 in the Appendix A.

Table 3 also shows the pairwise correlation between all of the study's selected variables. The correlation is between the dependent variable (EF) and the explanatory variables but for renewable energy efficiency. At the same time, it is lowest (0.04) between two pairs of variables, renewable energy coefficient and renewable energy use, and freedom to trade and government size.

TABLE 3 Correlations

| | EF | GDPc | REU | POP | REF | GS | LSPR | FT | REG |
|---|---|---|---|---|---|---|---|---|---|
| EF | 1.00 | | | | | | | | |
| GDPc | 0.24 | 1.00 | | | | | | | |
| REU | 0.36 | 0.51 | 1.00 | | | | | | |
| POP | 0.31 | 0.40 | 0.84 | 1.00 | | | | | |
| REF | −0.19 | 0.06 | 0.04 | −0.43 | 1.00 | | | | |
| GS | 0.79 | 0.30 | 0.52 | 0.47 | −0.21 | 1.00 | | | |
| LSPR | 0.69 | 0.11 | −0.01 | −0.01 | −0.18 | 0.31 | 1.00 | | |
| FT | 0.21 | −0.57 | −0.38 | −0.30 | −0.22 | −0.04 | 0.25 | 1.00 | |
| REG | 0.71 | 0.46 | 0.51 | 0.36 | 0.11 | 0.54 | 0.21 | −0.22 | 1.00 |

TABLE 4 Cross-sectional dependence tests for models I and II

| | CD test | | | Slope heterogeneity test | |
|---|---|---|---|---|---|
| Models | Pesaran CD test | Frees CD test | Friedman CD test | $\Delta$ | $\Delta_{adj}$ |
| EF = *f*(GDPc, REU, POP) | −0.112 | 0.733 | 13.378** | 5.066*** | 6.030*** |
| EF = *f*(REF, GS, LSPR, FT, REG) | 0.589 | 0.515 | 18.106*** | 1.772* | 2.310** |

*Note*: (.) represents probability value while ***, **, and * denotes level of significance at 1%, 5%, and 10%, respectively.

## 4 | PRIORI ESTIMATION AND RESULTS

To convey the findings credibly, we use a five-step procedure. In the first step, we investigate cross-sectional dependence (CD) and slope heterogeneity (SH). We employed different tests for the CD test while using the Pesaran and Yamagata (2008) slope heterogeneity test. The spillover impact of a shock from one cross-section to another in the panel dataset is referred to as CD. Its correct examination is essential because its occurrence may lead to erroneous conclusions (Pesaran, 2007; Syed et al., 2022). The results of the CD test and SH test are presented in Table 4. The null hypothesis of no cross-sectional dependence is rejected only for the Friedman CD test. At the same time, Pesaran and Frees indicate the acceptance of the null hypothesis for both models. In contrast, the slope heterogeneity test results show its existence for both models since the null hypothesis cannot be rejected.

Subsequently, in the second step, we examined all the variables' stationarity properties. This step is imperative to obtain reliable results. Although there are other stationarity tests for panel data in the literature, the majority of them do not tackle the CD problem. As a result, the outcome of these tests may be unreliable in panel research. The CIPS and CADF unit root tests, on the other hand, cover the CD; hence they perform better than others. As a result, we used the CIPS and CADF unit root tests, which are summarized in Table 5. The results show that we could not reject the null hypothesis using CIPS for all variables except for EF, REF, and GS, while we could not reject the null hypothesis using CADF for all variables except for FT. However, the null hypothesis could be rejected at the first difference for each variable, implying that the selected variables are stationary at first difference, except for POP in the CIPS test and GDPc and POP using the CADF test.

TABLE 5 Unit root tests

| | CIPS test | | CADF test | |
|---|---|---|---|---|
| | Level | 1st difference | Level | 1st difference |
| EF | −2.35** | −4.074*** | −2.204 | −2.623*** |
| GDPc | −1.379 | −2.733*** | −1.877 | −2.051 |
| REU | −2.155 | −4.120*** | −1.900 | −2.604*** |
| POP | −2.121 | −1.498 | −1.898 | −1.857 |
| REF | −2.271* | −4.504*** | −1.365 | −2.900*** |
| GS | −2.773*** | −4.884*** | −1.700 | −3.119*** |
| LSPR | −1.851 | −3.708*** | −1.838 | −2.871*** |
| FT | −2.193 | −3.867*** | −2.529** | −3.054*** |
| REG | −1.634 | −3.078*** | −1.768 | −2.697*** |

*Note*: Critical value of CIPS and CADF at 1% is −2.6, ***, **, and * represents the level of significance at 1%, 5%, and 10% levels of probability, respectively.

In step 3 we look at cointegration, which shows the long-term relationship between all of the variables in this study. The Pedroni Cointegration test, a first-generation test, was used to investigate cointegration. Table 6 shows the result, and the null hypothesis of no cointegration could only be rejected for the Modified Phillips–Perron test (MPPt) against the other two test statistics (PPt and ADFt). As a result, the MPPt is considered a better choice because it provides modified statistics with respectable power and is free from size distortion (of root error) problems (Perron & Ng, 1996). Thus, it can be concluded that the selected variables in this study have a long-run relationship.

For the long-run elasticity, the fourth step employs the augmented mean group (AMG), and common correlated effects mean group (CCEMG) estimators. The use of AMG and CCEMG is motivated by two factors: (1) these procedures cover CD and slope heterogeneity test (Pesaran, 2006); and (2) there was no requirement to investigate the stationarity and co-integration before using these techniques (Anser et al., 2021). The results of the AMG and CCEMG estimators for the two models are presented in Table 7.

## 4.1 | Long-run results and discussion

For model I, the AMG and CCEMG estimators show that REF was significant at 10% and 5% in AMG and CCEMG, respectively. However, the remaining variables were insignificant. The REF value for AMG is −0.012, implying that a percent increase in renewable energy efficiency coefficient will plunge the ecological footprint by 0.012, thus indicating that renewable energy efficiency expectedly plays a desirable role of driving environmental sustainability in the panel countries. In the CCEMG model, the value of REF is −0.010, depicting that a percent increase in renewable energy efficiency coefficient will lead to a decrease in the ecological footprint by 0.01, thus aligning with the AMG result. The result implies that using renewable energy decreases the ecological footprint, as illustrated in the previous study by Bekun et al. (2019). The gross domestic product per capita and the coefficient of the population are not statistically significant. Although evidence from extant studies show an ambiguity about the role of population, income has largely been seen to promote environmental degradation especially at the early stage of growth of an economy.

On the other hand, the AMG and CCEMG estimators for model II show that all the economic freedom aspect variables are statistically significant at the 1% probability level except for REU, which is statistically insignificant. The coefficient for GS is 0.209, indicating that a percent increase in government size increases the ecological footprint by 0.209%, indicating that government size worsens environmental quality. This result agrees with prior research by Chen (2022), who confirmed that government size positively increases $CO_2$ emission. The LSPR coefficient was 0.205, implying that a 0.205% surge in ecological footprint was caused by a percent increase in legal system and property rights. The findings are comparable to and negate the findings of Chapron et al. (2017) and Yamineva and Liu (2019). The two aforementioned studies found that the legal system is vital in safeguarding environmental legislation and implementing climate policy across borders. In the same light, the coefficient of FT is 0.195, which implies that a percent increase in freedom to trade internationally will foster ecological footprint by 0.195%. Finally, the coefficient of REG is 0.219, indicating that a percent increase in regulation will lead to a 0.219% increase in the ecological footprints.

The CCEMG produced similar results to the AMG. The value of REU was statistically insignificant, while the remaining variables were statistically significant at 1%. The value of the GS, LSPR, FT, and REG coefficients are 0.180, 0.200, 0.243, and 0.183, respectively, indicating that an increase in these variables leads to a surge in the ecological footprints.

### 4.1.1 | Robustness results and discussion

In a robustness estimation routine, the Random Effect (RE) and Fixed Effect (FE) regressions are employed for both models I and II. This approach in essence addresses the issue of time-invariant variables that can jointly affect the ecological footprint. The result for the first model is displayed in Table 8. The coefficient of REF is negative and significant across both specifications. This consistent pattern of REF on ecological footprint is our first major finding. In the RE regression, the value of REF is −0.003, implying that a 1% increase in the renewable energy efficiency coefficient will lead to a decline in the ecological footprint. The population coefficient is negative and significant at the 1% probability level. Even though the coefficient is small (−5.77e−09), the result implies that an increase in population will lead

**TABLE 6** Pedroni cointegration test

| Statistics | Value | *p* value |
|---|---|---|
| MPPt | 3.51*** | .00 |
| PPt | 0.76 | .22 |
| $ADF_t$ | 0.77 | .21 |

*Note*: ** indicates the level of statistical significance at 1% level of probability.

**TABLE 7** AMG and CCEMG estimators

| | Model I | | Model II | |
|---|---|---|---|---|
| Variable | AMG estimator | CCEMG estimator | AMG estimator | CCEMG estimator |
| GDPc | 3.49e−06 | −2.58e−06 | | |
| POP | 1.36e−07 | 4.61e−08 | | |
| REF | −0.012* | −0.010** | | |
| REU | | | 1.77e−07 | 3.99e−07 |
| GS | | | 0.209*** | 0.180*** |
| LSPR | | | 0.205*** | 0.200*** |
| FT | | | 0.195*** | 0.243*** |
| REG | | | 0.219*** | 0.185*** |

***, **, and * indicates the level of significance at 1%, 5%, and 10%, respectively.

**TABLE 8** Model I

| Variables | Pooled OLS (1) | Random effect (2) | Fixed effect (3) |
|---|---|---|---|
| GDPc | 8.05e−06*<br>(4.45e−06) | | |
| REF | −0.001<br>(0.001) | −0.003***<br>(0.001) | −0.001*<br>(0.0009) |
| POP | 7.82e−10<br>(4.78e−10) | −5.77e−09***<br>(1.61e−09) | −1.59e−08***<br>(2.28e−09) |
| *R*-squared | 0.12 | 0.29 | 0.38 |
| *F*-statistic | 5.43*** | 28.00*** | 33.88*** |
| Hausman test | | RE is selected | |
| Diagnostics | | | |
| Box–Pierce autocorrelation | 96.47*** | | |
| Multicollinearity (Mean VIF) | 1.42 | | |
| Heteroscedasticity | 49.86*** | | |

***, **, and * indicates the level of significance at 1%, 5%, and 10%, respectively.

**TABLE 9** Model II

| Variables | Pooled OLS (1) | Random effect (2) | Fixed effect (3) |
|---|---|---|---|
| REU | 2.58e−08 | −4.31e−07* | −8.47e−07** |
| GS | 0.193*** | 0.189*** | 0.184*** |
| LSPR | 0.198*** | 0.213*** | 0.212*** |
| FT | 0.183*** | 0.174*** | 0.170*** |
| REG | 0.200*** | 0.207*** | 0.208*** |
| *R*-squared | 0.99 | 0.97 | 0.97 |
| *F*-statistic/Wald | 3740.02*** | 4413.49*** | 714.54*** |
| Hausman | RE is selected | | |
| Diagnostics | | | |
| Box–Pierce autocorrelation | 47.10*** | | |
| Multicollinearity (Mean VIF) | 1.58 | | |
| Heteroscedasticity | 29.92* | | |

***, **, and * indicates the level of significance at 1%, 5%, and 10%, respectively.

to a decrease in ecological footprint, thus providing a pathway toward environmental sustainability. The result of the FE regression is similar to that of the RE regression, with REF negative and significant at the 10% probability level, implying that an increase in REF will lead to a decline in EF. The population coefficient is also negative and statistically significant at the 1% probability level, denoting that an increase in population will reduce EF. Although the result is surprising as it negates a priori expectation, this could possibly be justified by the increasing environmental awareness of the society, which could translate to responsible environmental practices. Moreover, literature noted an inconclusive outcome in the study of the nexus of environmental quality and several socioeconomic indicators such as population/urbanization, globalization, and others. The diagnostics reveal the absence of autocorrelation and multicollinearity.

The robustness result for the second model is shown in Table 9. From the Hausman test, RE is the appropriate regression for this model while the heteroscedasticity issue is also corrected in subsequent procedure. REU was negative and significant at 10% in the RE regression, which is the second major finding of this paper. A 1% increase in REU will decrease the ecological footprint by a small margin of 4.31e−07 percent (a significantly small value). Our major findings from the two models on the negative impact of renewable energy as well as renewable energy efficiency coefficient are supported by Qiao et al. (2019) and Yu et al. (2020). However, the findings of Alola and Joshua (2020) and Alola et al. (2022), who both showed a positive link between renewable energy and ecological footprint in their studies, contradict our result. The negative values of REF and REU show that renewable energy is a tool for mitigating the ecological footprint, implying that the G-7 countries with higher use of renewable energy or high share of renewables in the energy mix are on course to reduce the effect of the ecological footprint on the climate.

Interestingly, the other variables included in the model were found to be all positive and significant at the 1% probability level (see Table 9). The result shows that a 1% increase in GS, LSPR, FT, and REG will all lead to a surge in the ecological footprint by 0.189%, 0.213%, 0.174%, and 0.207%, respectively. The government size escalates the ecological footprint, implying that big governments have big economic components, thus causing a decline in the quality of the environment because of substantial industrial and economic activities. This result is consistent with prior research noting that large government sizes lead to environmental pollution (Chen, 2022; Islam & López, 2015; Lan et al., 2022; Ullah et al., 2020).

Furthermore, the findings show that legal systems and property rights have a considerable positive impact on the G-7 countries' environmental footprint. In a recent study by Alola et al. (2022), a similar result is also observed for the case of the European Union countries. The RE regression shows that when legal systems and property rights improve, the ecological footprint increases dramatically. This means that strengthening judicial performance, boosting the accountability and independence of the G-7 legal systems, and improving property rights constitutes a threat to the investigated counties' environmental quality. The economic logic can be interpreted from the standpoint that a better legal system and property rights would result in increased growth and economic prospects, hence increasing demand on the ecosystem. It further suggests that legal systems and property rights may not appropriately account for or encompass the environmental aspects considering that environmental law/regulation and environmental-related property right are now being explored separately in most advanced economies. The result also shows that an increase in FT will lead to an adverse impact on the environment. An increase in the FT of the G-7 countries, in particular, may have aided those countries in expanding their economies while also increasing their ecological footprint proportionally. The value of REG (which represents business, labor, and monetary freedom) affects the environment by increasing ecological footprints in the G-7 countries. This result is in harmony with Alola (2019) and Adedoyin et al. (2020). The diagnostic result shows no evidence of autocorrelation and multicollinearity.

## 5 | CONCLUSION AND POLICY IMPLICATION

While literature has shown the different views about the environmental sustainability trend of the advanced economies and economic blocs such as the G-7, there is limited information about the role of these aspects of economic freedom. In the current scenario, by using the historical dataset for the period 2000–2016, the roles of the broad aspects of economic freedom, that is, rule of law, government size, regulatory efficiency, and open market alongside the GDP and renewable energy usage in the changes in ecological footprint of the G-7 countries, are examined. After performing a series of priori estimations, the AMG and CCEMG were employed alongside the robustness approaches (Pooled OLS, RE, and FE) that offer insightful results.

Given the summary of the results from the empirical approaches, renewable energy use and renewable energy efficiency is found to mitigate ecological footprint, thus improving environmental sustainability in the panel of G-7 economies. Additionally, significant evidence revealed that population is not detrimental to environmental sustainability because it shows that ecological footprint declines with population over time in the countries. Importantly, all the four main economic freedom aspects, that is, government size, legal system and property rights, freedom to trade internationally, and regulation are not desirable to promoting environmental quality in the panel estimation. Although this study posits an interesting dimension in the ecological sustainability literature, there are potential pathways toward improving the weakness associated with the current study. For instance, future study could deepen the investigation by accommodating all the 12 quantitative and qualitative aspects of economic freedom in both panel and country-level study. However, the significance of this novel revelation is that it offers useful policy insight to the G-7 and the specific countries under examination.

### 5.1 | Policy recommendation

Although the energy transition policy in the understudied countries seems to have yielded a desirable environmental effect, more could be done in that direction in order to complement such reported success. For instance, the countries could be urged to further increase the share of clean and renewable energy financing, expand the subsidy portfolio and option for clean energy development from both the consumer and producer perspectives. Policy framework could be fine-tuned to encourage more expansive and adaptable energy-intensive infrastructure development (such as green transportation and buildings) that is based on clean and renewable energy technologies in order to spur demand for those energy sources. On the aspects of economic freedom, relevance policy suggestions could be deduced from each of the fours aspects economic freedom indicators. The first is that policymakers should adopt a holistic approach toward improving ecological sustainability by advocating for increased adoption of environmentally friendly practices in all the 12 dimensions of economic freedom (property rights, government integrity, judicial effectiveness, government size, government spending, tax burden, fiscal health, regulatory efficiency, business freedom, labor freedom, monetary freedom, open markets, trade freedom, investment freedom, and financial freedom). Second, as seen in the specificity and adoption of environmental laws/regulations, applied as an extension of legal system, the environmental performance of other aspects of economic freedom could be driven by adopting a specified environmental framework for the respective EF aspects. Specifically, considering that the size of government is a function of employment, revenue, or expenditure, these components could be harnessed in along green path in order to improve on the environmental sustainability while not necessarily reducing the size of government. Additionally, the 21st century international trade opportunities among countries should be primarily enhanced by environmental instruments that offers environmental benefits rather than the traditional benefits that is centered on comparative advantage. Lastly, the policy of inclusivity of environmental aspects to government regulations at levels could further promote environmental sustainability.

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## APPENDIX A

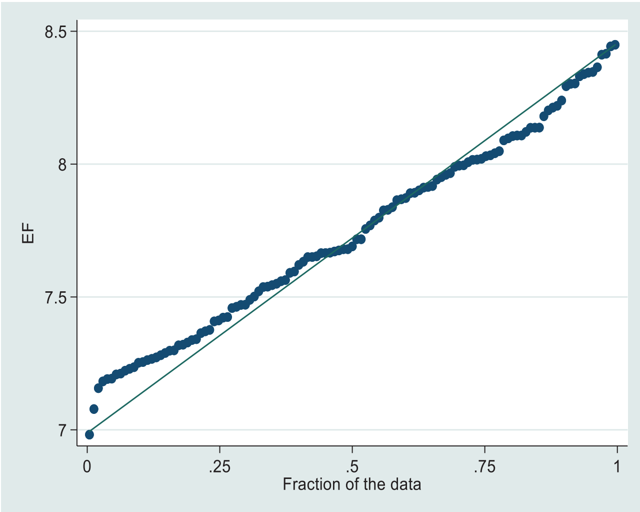


**FIGURE A1** Q–Q plot of EF [Colour figure can be viewed at wileyonlinelibrary.com]

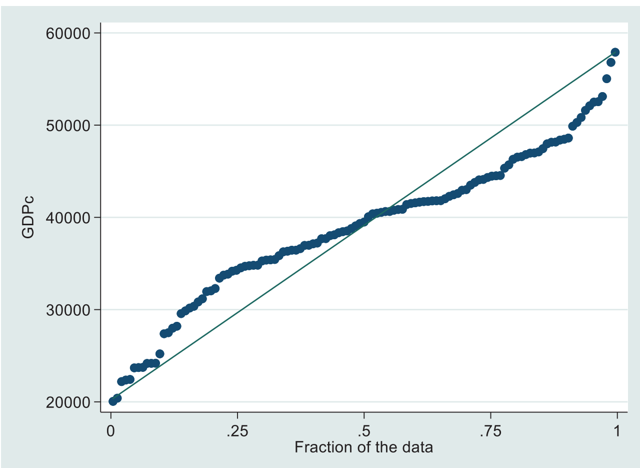


**FIGURE A2** Q–Q plot of GDPc [Colour figure can be viewed at wileyonlinelibrary.com]

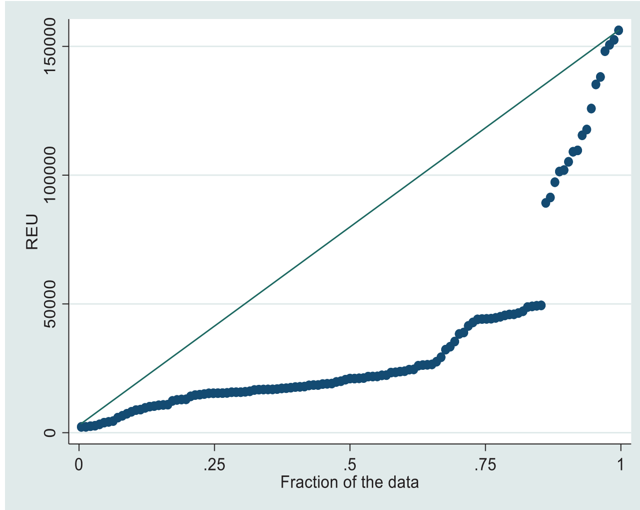


**FIGURE A3** Q–Q plot of REU [Colour figure can be viewed at wileyonlinelibrary.com]

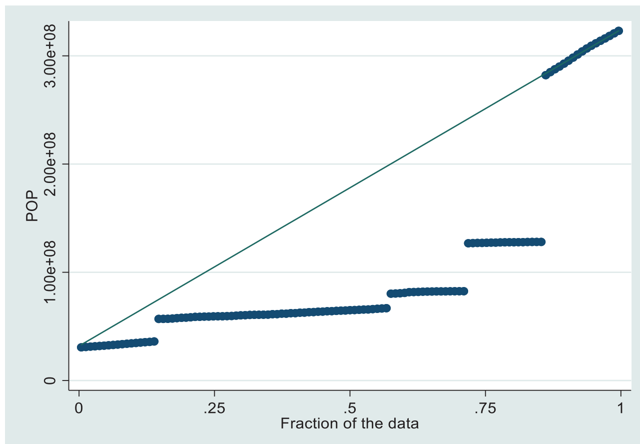


**FIGURE A4** Q–Q plot of POP [Colour figure can be viewed at wileyonlinelibrary.com]

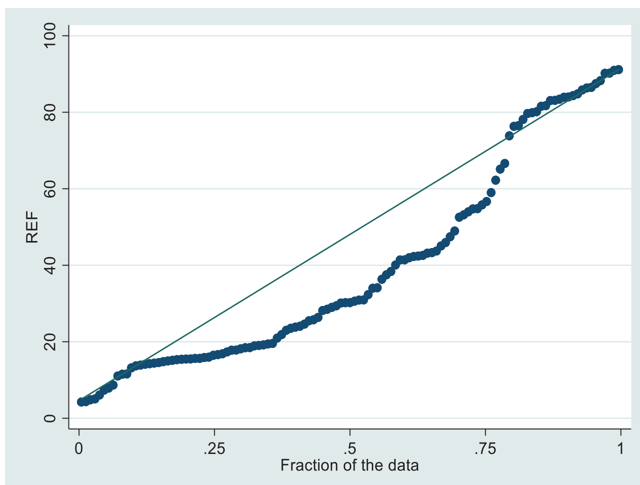


**FIGURE A5** Q–Q plot of REF [Colour figure can be viewed at wileyonlinelibrary.com]

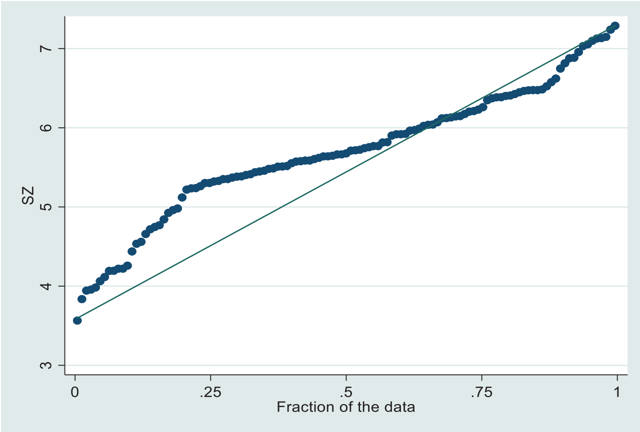


FIGURE A6 Q–Q plot of SZ [Colour figure can be viewed at wileyonlinelibrary.com]

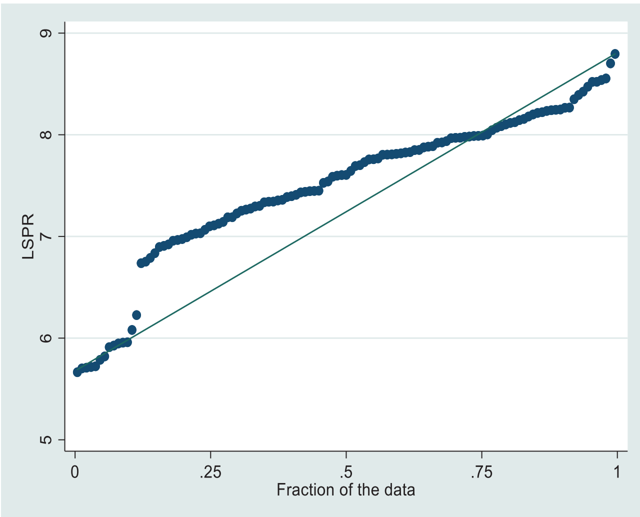


FIGURE A7 Q–Q plot of LSPR [Colour figure can be viewed at wileyonlinelibrary.com]

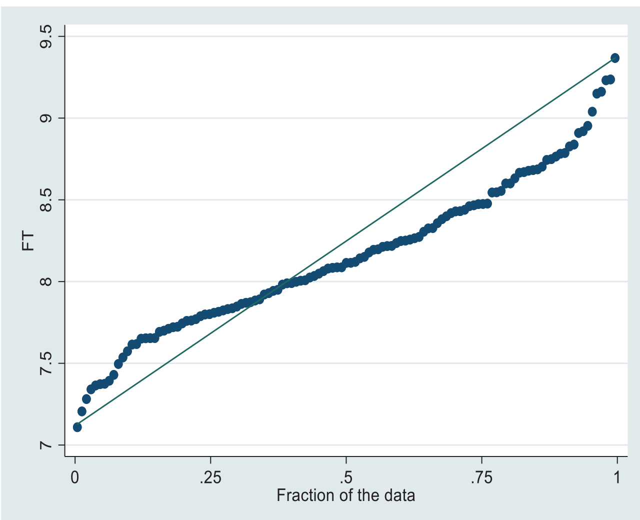


FIGURE A8 Q–Q plot of FT [Colour figure can be viewed at wileyonlinelibrary.com]

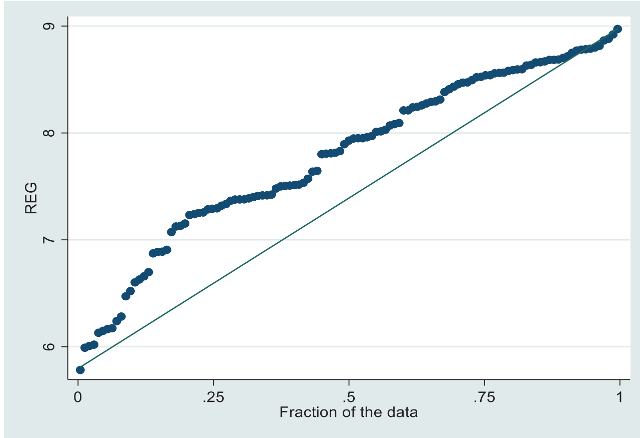


FIGURE A9 Q–Q plot of REG [Colour figure can be viewed at wileyonlinelibrary.com]