Received: 01 July 2023 | Revised: 25 August 2023 | Accepted: 27 August 2023
https://doi.org/10.56946/jeee.v2i2.343
Journal of Environmental and Energy Economics

Research Article

Environmental Sustainability in France: The Role of Alternative and Nuclear Energy, Natural Resources, and Government Spending

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Abstract
The worldwide community is worried due to various ecological modifications. The change of climate, desertification, logging, coastal erosion, overfishing, loss of biodiversity, and soil resource depletion are all causes that contribute to ecological harm. Quite a few observers have pointed out that these problems add up to substantial alterations to Earth's surface brought about by human activity. Using the framework of the environmental Kuznets curve (EKC), this investigation analyzes the influences of alternative energy resources and natural resources alongside government spending on France's ecological sustainability throughout 1990-2021. Long-run estimates are calculated with completely modified least squares (FMOLS), and the empirical analysis's robustness is examined with dynamic ordinary least squares (DOLS). Long-term estimations show an opposing association concerning carbon dioxide (CO_2) emissions with renewable and nuclear energies, natural resources, and government spending, whereas a positive liaison between CO_2 emissions with economic development. However, CO_2 emissions have a negative association with the square of economic progression, lending credence to EKC. As the economy grows, environmental sustainability declines. In the long run, EKC will help the environment progress for the better. Implications for policy, research gaps, and future directions are discussed to round out the study.

Keywords: Carbon emission; Environmental sustainability; Alternative energy; Natural resources; Government expenditure.

Introduction

Energy conservation cut down demand and lowers ecological impacts because bulk of the energy derives from non-renewable fossil fuels [1]. Saving money and helping the environment are just two of the many benefits of cutting back on energy use [2]. Air quality issues and acid rain are just two examples of the environmental concerns that have influenced the advancement of the energy practices [3]. Investing and other efforts to grant affordable, assured energy are influenced by and adjusted in response to a wide range of environmental conditions. Since the energy sector is responsible for more than three-quarters of global GHG emissions, there is growing concern about the sector's vulnerability to climate change policy [4]. Energy and environmental policy are intertwined in ways that make it urgent to learn how to encourage synergies between them. Investing in renewable energy and selling off high-emission assets are both necessary steps in the fight against climate change [5]. Path dependence and lock-in may result from constructing infrastructure that lasts for decades. A quicker shift away from these resources than the replacement of natural infrastructure is needed to keep temperatures below 2 °C.

The energy sector is the primary source of heat-trapping greenhouse gas (GHG) emissions due to its reliance on the combustion of fossil fuels. Air pollution, triggered by the arson of fossil fuels, is a foremost worldwide environmental problem with skyrocketing financial and human health implications [6]. Energy is a vital component of every thriving economy. But it creates major challenges for the generation and use of energy because of this [7]. Air pollution and GHG emissions are interconnected in many ways, and there are various chances to act jointly to find solutions to these problems [8]. Significant progress has been made in this area through the relationship concerning lowering air pollution coupled with GHG emissions, which is not necessarily favorable [9]. It's straighten that lots of nations want to tackle these twin issues, but finding a workable solution could be challenging. Different approaches to the problem in China and the United States provide insight into the way these two countries deal with crises [10-12].

Air pollution, including particulate matter, sulfur dioxide, and mercury emissions, is a serious problem, thus many countries have instituted stricter air quality rules in recent years [13,14]. To reduce our carbon footprint and our GHG emissions, we must follow these rules and we will [15]. How these synergies are achieved and by whom, concerning the experiences of the European Union, the United States, and Canada, as well as other regions are provided [1,12,16]. Emissions of CO_2 may go down or up significantly depending on many other factors, including the economics of coal- and gas-fired electrical energy production and projections for the forthcoming [17]. Multipollutant methods that take a holistic approach should be emphasized because of their many benefits [18]. With a new National Low-Carbon Strategy and a 10-year Energy Transition Strategy, France formally committed to reaching carbon neutrality by 2050 in 2019 as part of its energy transition framework [19]. France's shift to renewable energy has been plagued by delays, and difficulties persist despite ongoing changes. As part of its plan for economic recovery from the COVID-19 crisis of this century and its investment plan for 2030, the French government is investing in hydrogen infrastructure, promoting sustainable mobility, and retrofitting existing buildings to speed up the country's energy transition [20,21]. Many of France 2021's suggestions center around helping the country's attempts to deal with energy and climate change in some way [22]. If France is serious about meeting its climate change goals, it must move quickly to implement the energy transformation's key components. The nation has acted a crucial position in steering global initiatives to combat climate change. The government needs to make important choices about its energy mix in the future, says the International Energy Agency. The 2021 Energy Policy Review states that the French government is not moving fast enough to implement low-carbon energy production technologies and solutions to accomplish its energy and climate objectives. For the International Energy Agency's energy and climate goals to be realized, more policy actions and investments are needed [23]. France has long been a leader in efforts to improve global climate [24]. It played a pivotal role by contributing to the European Union framework by signing the remarkable Paris Agreement in 2015. This action is consistent with the goals of the Paris Agreement.

By the year 2030, the EU hopes to have reduce emissions by 55 percent [25]. The French authority is acting swiftly to achieve net zero emissions by 2050 [21], making it one of the first countries in the world to implement a climate law. The French government has actively supported "green finance," and a new method of budgeting helps to ensure that environmental and climate change spending priorities are met. Building retrofits and low-carbon transportation options are available through both the economic recovery plan and the government's 2030 program, two of the magnificent renewable energy transition plans in the world. Plans to modernize the nuclear power facilities, in particular, will compel the French authority to pick significant decisions if the country is to meet its goal of net-zero emissions by 2050 [22]. For France to achieve its goal of zero emissions by 2050, it must make choices on how its future energy system will be conceived. France's government wants to slash its energy use in half. Investment in nuclear power, energy efficiency, and renewables may do this between 2012 and 2050 if they were to rise in size [19]. According to the French National Low-Carbon Strategy, cutting energy use is a top priority. Building codes and product restrictions have gotten stricter over the past two decades, with the largest efficiency gains occurring in the residential and service sectors. However, rehabilitation rates fell slightly, and few efficiency boosts were made in the transportation segment. Almost half of France's renewable energies are from hydroelectric power plants that were constructed decades ago despite the country's efforts to diversify its energy sources [26]. Boost signature initiatives, streamline permissions, and synchronize local, state, and federal goals. It is the goal of the federal government to hasten the growth of solar and wind power. As Zeraibi et al. [22] point out, the work is well worth it. However, success is less likely without more consistent and long-lasting policies.

The fundamental concern of this research was how the spread of alternative and nuclear energies in France would affect the country's ability to maintain a healthy ecosystem. Decarbonizing all segments that rely significantly on fossil fuels at present is vital as part of the effort to construct a carbon-neutral global economy [20]. Transportation, especially large-scale maritime and aerial transport, and industrial activities requiring combustion are also good examples. However, nuclear power generates about 10% of the globe's electrical energy [27]. It has a modest carbon impact and is the second greatest resource of low-carbon energy in the globe, next hydropower. Nuclear technology may also be utilized to lessen the impact on the environment outside of the electricity sector by cutting down on emissions. Coal-fired facilities have much higher air pollution and CO_2 emissions than other energy sources like wind, solar, and natural gas, therefore making the switch will cut CO_2 emissions from the electrical sector. Therefore, changing from coal to gas to generate electricity is probably the best fuel option right now. However, gas is still not a carbon-free fuel, and some emissions of CO_2 will be produced yet if they are greatly decreased. Switching to fuels with low or no carbon content is essential to lowering CO_2 emissions as much as is practical [28]. It is possible to cut annual coal usage in half, from over nine to lower than three billion tons, ensuing in a reduction in CO_2 emissions of 7.2 trillion tons. GHG emissions from chemical besides industrial procedures, renewable energy techniques, and transport might all be reduced if hydrogen were used instead of fossil fuels in these areas. At present, most French hydrogen is yielded using steam methane restoring, a method that requires a huge extent of energy and results in annual CO_2 emissions that are roughly equal to those of the United Kingdom and Indonesia put together. Beside providing electricity and heat, nuclear power may also be utilized to efficiently manufacture hydrogen without releasing any CO_2 [20,26].

Light from the sun, air, water, soil, rocks, plants, and animals are only a few of Earth's various components. Natural resources can be protected through natural heritage programs and nature reserves. Particular ecosystems (like the rainforest in Fatu-Hiva) are often cited as examples of bio- and geodiversity in scientific literature. The possible impression of natural resources on France's environment is also investigated. Iron ore, sulfur, salt, bauxite, uranium, zinc, and arsenic are only a few of France's many minerals and metals. The country also produces a lot of renewable energy and has a sizable wood and fishing economy. The shocking factor concerning France is that it has such meager resources. Heavy mining throughout the Industrial Revolution, which was pivotal in making France what it is today, exhausted vast swaths of France's natural mineral resources. Coal, iron ore, bauxite, and uranium are all thought to be in plentiful supply in France. Their shallow depths and challenging extraction make them inappropriate for steel manufacturing. It's a shame that the local iron ores aren't of higher quality. Ores rich in uranium are extremely rare. Note that the natural gas resources uncovered in 1951 at Lacq in the Pyrenees are virtually depleted and that there are almost no petroleum deposits in the Pyrenees. Hydroelectric production has increased significantly, yet it is still not enough to meet France's needs. In addition, high-quality soils cover almost half of France's territory, allowing the country to become a significant food exporter due to an agricultural surplus.

The effects of the French government's spending on final consumption and the growth of the economy on environmental sustainability are also analyzed here. Government spending in 2020 was roughly 61.78% of GDP when adjusted for tax receipts [29]. Governments around the world have recently increased spending as a response to the ongoing economic crisis. The level of government expenditure depends on the health of the economy and other factors. The nature of the ecosystem is profoundly impacted by government spending [30]. The impact of investment, public spending, and ecological health is dissected here. Although government spending may have a major effect on the environment, this topic has received little attention in the literature. The government's spending has direct and indirect effects on the ecosystem. Increases in government spending are associated with a greater risk of redistribution [31]. The upshot is increased income parity and better ecological conditions for all. Large governmental entities are only likely to request environmental protection if it is a high-end amenity. Scale, mounting ecological burdens, compositional increases in human capital, intensity of actions over physical capital-intensive productions that are further detrimental, techniques due to amended labor efficacy, and rising incomes all contribute to the possibility of a rise in pollution levels. However, the existing literature focused on investigating the energy-economy-environment nexus, leaving behind a research gap in investigating the environmental impacts of alternative and nuclear energy, natural resources, and government spending [28,32]. France's support for nuclear and alternative energy development is not mentioned anywhere in the contemporary literature. Based on the EKC, this research explores the impacts of alternative energies, natural resources, and government spending on France's ecological attribute throughout 1990-2021. France has not yet looked at the complicated relationships between environmental preservation, fiscal policy, and economic development.

Recessions besides financial catastrophes as diverse as the Great Depression, the Fukushima nuclear disaster, and the Eurozone crisis are all documented in French economic records for the studied period. Long-term projections are analyzed using the DOLS technique in the present study. In addition, FMOLS robustness testing was used in this study.

Literature Review

Carbon emissions are measured using a wide variety of mathematical models and theories because climate change is so pervasive. The study of CO_2 emissions has seen a proliferation of methods in recent years due to global warming and climate change caused by increased use of fossil fuels and deforestation [33]. When it comes to regression analyses of wealth and technology, the three most mentioned concepts are EKC, STIRPAT, and LMDI [34]. By researching the liaison involving GHG emissions plus economic progression, Grossman and Krueger [35] first articulated the concept of environmental quality. The authors then elaborate on why economic growth is fundamental to the EKC's definition of a thriving ecosystem. As a result, economic development is destructive to ecosystems. By employing the EKC model, Neagu [16] studied the correlation between the economic complexity index and carbon emissions in 25 randomly chosen member states of the European Union between 1995 and 2017. The EKC theory predicts that economic growth and pollution will have a U-shaped relationship. EKC tracks CO_2 emissions as a proxy for environmental stress. Several studies also reported that EKC is valid for specific countries [36]. However, numerous studies concluded that economic growth increases emissions [37,38]. In contrast, some studies reported that economic progression enhances ecological superiority by lowering emissions [39,40].

Environmental quality is heavily influenced by energy use [41]. However, renewable energy sources that are replenished through non-human means are considered sustainable. Geothermal energy is also included in this list of components. Fossil fuels are used at a rate far higher than renewable energy is produced [6]. It's not possible to rely on all forms of renewable energy forever. The current rate of extraction from biomass sources, for instance, is unsustainable. Renewable energy not only generates electricity, but also warms or cools the air and water, powers vehicles, and powers off-grid communities [42]. Solar and wind power account for about 30 percent of global energy use. However, just 8% of the world's energy needs are met by conventional biomass. More than 4% of annual energy use comes from solar water heating, while over 6% comes from solar electricity. Hybrid electric and solar systems, as well as renewable energy sources like solar and wind power, are on the table as potential energy sources [43]. Many different types of compact solar power systems can now be purchased and installed to provide electricity for homes and modest businesses. GHG emissions can be drastically cut with the use of a hybrid energy scheme that links nuclear and renewable energy sources [11]. By using different econometric methods, several studies reported that renewable energy helps to improve the environmental quality by reducing emissions [44-48].

The major goal of the energy transition is to switch to renewable energy sources including wind, solar, biofuels, hydro, and others that have negligible or even negative carbon footprints. Syed et al. [49] used the asymmetric ARDL approach to analyze the unequal effects of nuclear power and economic development on India's carbon emissions between 1975 and 2018. Using nuclear energy instead of fossil fuels led to lower CO_2 emissions in India. Using data from 1970 to 2016, Ozgur et al. [50] examined the impact of nuclear energy use on CO_2 emissions in India using the Fourier Autoregressive Distributed Lag model to verify the EKC hypothesis. Both the GDP and GDP square coefficients predicted by the EKC are shown to be statistically significant in India. The statistical significance of the negative coefficient of nuclear energy suggests that expanding nuclear energy is crucial to succeeding clean plus sustainable development as a policy target. Kartal et al. [12] examined how switching to nuclear and renewable energy sources would affect CO_2 emissions in the United States. The data showed that both nuclear and renewable energy are beneficial to the environment.

Jahanger et al. [27] used moments quantile regression to study the influences of atomic energy on carbon emissions for top nuclear energy nations throughout 1990-2017. Nuclear energy is a sustainable alternate to traditional fossil fuels since it reduces CO_2 emissions across all quantiles. The results not only validate the anti-correlation between polynomial economic growth (squared GDP) and CO_2 emissions but also provide strong support for the EKC theory. Carbon emissions, nuclear energy, globalization, and technological innovations in the top ten countries using the most nuclear energy from 1990 to 2017 were evaluated by Sadiq et al. [28], while economic growth and renewable energy sources were also taken into account. The data showed that decreasing carbon emissions is one way in which nuclear power and technological progress save money in protecting the environment. The impact of technological advancements in alternative energy production on GHG emissions was studied by Yang et al. [11]. The research, which looked at 30 provinces in China from 1997 to 2017, found that there was an inverse relationship between technological advances in alternative energy production and increases in CO_2 emissions.

Tufail et al. [51] first introduced the effect of fiscal decentralization and natural resources rent on CO_2 emissions using panel data from seven highly fiscally decentralized OECD nations from 1990 to 2018. Long-term findings verified that fiscal decentralization and renting natural resources reduce CO_2 emissions, which is good for the environment. Adebayo et al. [52] examined the interplay between technological advancement, renewable energy consumption, natural resource availability, and CO_2 emissions in the BRICS countries from 1990 to 2019 to achieve the goal of reducing CO_2 emissions set at the Paris Climate Conference (COP-21) for the sake of environmental sustainability. CO_2 emissions are reduced due to the use of renewable energy and natural resources, the study found. Furthermore, the synergy between technical advancement, the rental value of natural resources, and the use of renewable energy sources contributes to lower CO_2 emissions and enhanced environmental sustainability. The effects of climate mitigation technologies (renewable energy generation and usage) and natural resource management (rent and depletion) on China's GHG emissions were studied by Chien et al. [10]. From 1991 to 2021, the connection between the constructs was analyzed using a nonlinear ARDL technique. The results show that the usage of renewable energy and natural resource rent are inversely related to environmental degradation in China. Voumik et al. [39] used data from 1972 to 2021 to conclude that in South Asian countries, natural resource rent is more effective than electricity at preventing environmental degradation.

Few studies have looked at how government spending affects the environment and how different spending techniques affect the state of the domain. Government spending and its impact on the environment was the subject of an empirical study by Halkos and Paizanos [53]. CO_2 emissions were utilized as a surrogate for ecological quality by the study. They concluded that there are numerous connections between government spending and environmental quality. The effects of government spending policies on the natural world have been studied in depth for decades [54]. The conclusions indicate that authorities would reduce subsidies that harm the environment. For the sake of preservation, capitalization, and conservation, it must advocate for subsidies in the agricultural sector and promote donations of ecologically preferable equipment to the energy sector. Emission inequality is attributed to differences in government spending, energy consumption, and other socioeconomic factors by Fan et al. [55], examined the level and variations of China's CO_2 emission inequality throughout 2007-2015. Empirical results showed that regional emission differences required differences in economic stage, population, and energy formation; differences in government spending also played a significant role. The disparity in emissions was caused in large part by disparities in the composition of expenditures.

Furthermore, Wójtowicz et al. [56] looked into how government spending in different Polish regions affected CO_2 emissions. Using an LMDI approach, the researchers came up with their proprietary list of variables that affect CO_2 output. Public investments are found to reduce CO_2 emissions in a region, while investments in environmental protection are found to have the opposite effect. The impact of government spending on green economy performance in developed and developing countries was studied by Jin et al. [30]. The study used panel data on BRI countries from 2008 to 2018. The results add credence to the idea that R&D investments directly contribute to decreases in developed nations' CO_2 pollution levels. CO_2 emissions in Ghana were studied by Kwakwa [31], who looked at the results of industrialization, government spending, and the military. Researchers studied time series data from 1971 to 2018 using the STIRPAT framework. Income and carbon emissions were found to have a U-shaped connection using the ARDL regression method, lending credence to the environmental Kuznets curve concept. However, it has been demonstrated that government spending can cut carbon emissions.

Companies should adopt ecologically sustainable procedures, but these shouldn't be at odds with the company's aims. Thriving ecological sustainability initiatives could bring together people, the planet, and profit. Unrestrained consumption has been shown to negatively affect human well-being in many ways [11]. The growth of our economy has increased our energy consumption, which has led to an intensification in pollution and a exhaustion of natural resources in turn [12]. A company doesn't have to sacrifice creativity and innovation to achieve long-term success. Sustainability is essential to growth. Renewable energy businesses generate new jobs in the economy [43]. Using less energy and plastic in manufacturing can boost profits. Including environmental effects in a company's cost-benefit analysis isn't cheap, but it's a long-term investment in the health of the economy as a whole.

Can and Gozgor [57] used the DOLS approach to examine the factors that affect France's CO_2 emissions. The research analyzed the nexus involving economic intricacy, CO_2 emissions, and energy usage. The study's results support the EKC hypothesis in France. In addition, it was shown that cutting back on energy use can reduce CO_2 emissions. It has also been noted that a more complicated economic system results in lower CO_2 emissions. Using time series data from 1955 to 2016, Shahbaz et al. [24] looked into what factors contributed to France's carbon emissions. They found that FDI, financial extension, economic progress, energy utilization, and energy research advances all played significant roles. The study indicated that while breakthroughs in energy research hurt French carbon emissions, foreign direct investment had a beneficial effect. In addition, energy use is linked to GHG production. The EKC is supported by the fact that the correlation between economic expansion and CO_2 emissions took the form of a reverse U.

Furthermore, the projected EKC for France provided by Neagu [33] exhibits a clear U-shaped inversion. Omri and Saadaoui [19] used the non-linear ARDL method to analyze the impact of nuclear energy, fossil fuels, income, and trade on France's carbon emissions from 1980 to 2020. The relevance of the EKC assumption was also assessed. The most important finding was that using nuclear power in France helps to cut the country's carbon footprint. However, these emissions are exacerbated by the use of fossil fuels and the liberalization of commerce. However, the research showed that there is, in fact, an inverse U-shaped relationship between economic expansion and carbon emissions. This lends credence to the EKC theory. Zeraibi et al. [22] looked at how several factors including natural gas use, nuclear power, democracy, and access to banking have affected France's energy independence and carbon footprint. The ARDL model indicates that nuclear power, natural gas, and widespread access to financial services all harm the environment. However, nuclear power and democratic rules both help lower energy risks while raising prices. Furthermore, the study's findings supported the U-shaped EKC theory.

To lessen its dependency on fossil fuel imports and strengthen its energy security, France is investing more in renewable and nuclear energy. There is also a dearth of research into how natural resources and government spendings affect ecological attribute in France, although both are important factors. This study aims to fill a void in the literature by analyzing the impact of nuclear and renewable energy, as well as rent from natural resources and final spending by the French government, on the country's CO_2 emissions within the context of the EKC hypothesis.

Methodology

Theoretical framework

Several studies have explored the liaison among environmental sustainability, renewable energy use, and economic development. The linear and nonlinear consequences of economic expansion in France are analyzed, along with the effects on environmental sustainability, natural resource depletion, government spending, and more. Sunlight, wind, and water are the primary contributors to green energy. Carbon-emitting fossil fuels have kept the globe going for the past 150 years, but these renewable energy sources are the polar opposite. The nuclear power plant is the cleanest in the world. Many people believe that nuclear power is the cleanest form of energy available. Nuclear power has several advantages, such as its low carbon footprint and high efficiency, but it also has some drawbacks. The rising need for already scarce natural resources has been exacerbated by many causes, including population expansion and altered weather patterns. The water supply and watershed quality are deteriorating due to rising household, industrial, and agricultural demand. Therefore, watersheds and irrigated fields are losing their integrity and functionality.

Deforestation, overgrazing, salinization, and erosion are also on the rise. People living in poverty suffer because their main source of income, natural resources, are quickly being depleted. The government regulates polluters and ensures that water quality is maintained with tax dollars. In addition, the government regulates the extent to which some industries can harm the environment. The country's actual output will be influenced by economic growth because of the rise in economic activities. Therefore, rising manufacture and spending are prone to damage ecosystems. Some ecological impacts of economic development include increased temperatures worldwide, depletion of non-renewable resources, increased pollution, and diminished habitat. No method of economic growth is inherently harmful to the planet. When people have more disposable income, they can put more money into environmental causes. If we make enough technological strides, a thriving economy can help curb environmental damage. Economic expansion is thought to worsen the environment at first, but then enhance it once the post-industrial economy takes over [35]. Some obvious pollutants may follow a Kuznets curve, while others, especially those with a broader distribution, may not. However, rising prosperity does not slow the use of finite resources. The import of coal from poor countries is one example of how pollution reduction in one country can result in corrosion in another. Long-term environmental concerns are often overlooked in favor of more pressing challenges.

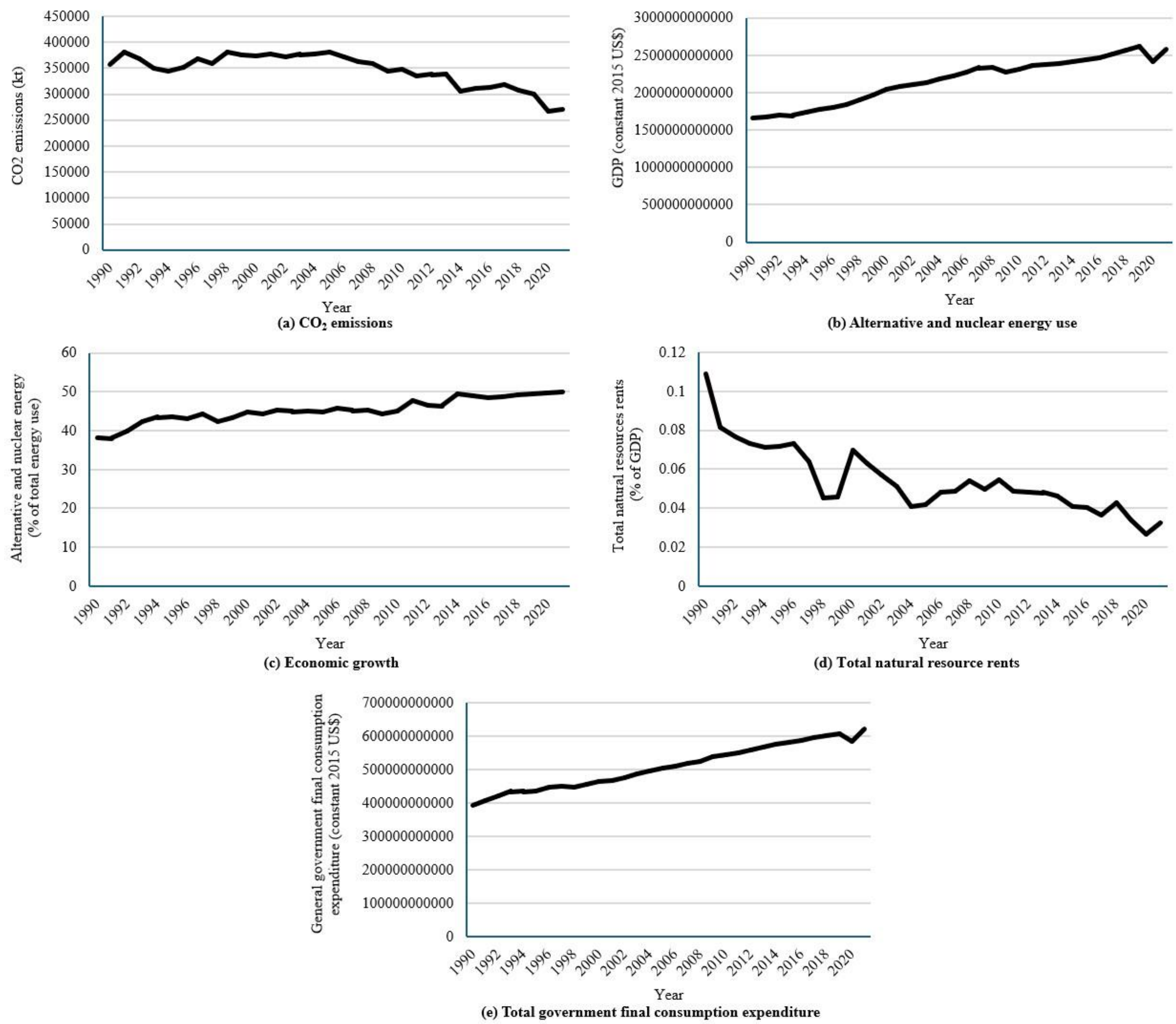


Figure 1. The annual trend of the variables.

Data description

From 1990 through 2021, this research uses the EKC to examine how the French government's spending on consumption, consumption by citizens, and the usage of alternative energy sources will affect France's environmental sustainability. Emissions of CO_2 are reported in kilotons (kt). The percentage of ultimate energy consumption that came from renewable sources and nuclear power was calculated. Total rents of natural resources as a % of GDP were also anticipated for this study. GDP was used because it is a consistent indicator of economic growth in 2015 US dollars. The amount of all government spending on final consumption is calculated in 2015 US dollars. All of the information for the yearly series comes from the World Development Indicators [29]. The variables' yearly changes are shown in Figure 1.

Econometric model

Based on the EKC, this research investigates the impacts of alternative energies and natural resources alongside government spending on France's ecological sustainability throughout 1990-2021. The empirical model is denoted by the subsequent equation:

$$C_t = \tau_0 + \tau_1 A_t + \tau_2 N_t + \tau_3 G_t + \tau_4 Y_t + \tau_5 Y_t^2 \quad (1)$$

where A is alternative and nuclear energy, N is natural resources, G is government consumption final expenditures, Y is the economic growth (GDP) and Y^2 is the square of GDP. Additionally, the dependent variable C is CO_2 emissions. Besides, τ_0 is the intercept and t reflects the time series (1990 to 2021). In addition, τ_1, τ_2, τ_3, τ_4, and τ_5 denote the coefficients.
Further Equation (1) can be expended as the econometric model in the following form:

$$C_t = \tau_0 + \tau_1 A_t + \tau_2 N_t + \tau_3 G_t + \tau_4 Y_t + \tau_5 Y_t^2 + \varepsilon_t \quad (2)$$

where ε_t stand for the error term.
However, all the data was transformed in their logarithmic forms for the analysis to confirm the data normality. Thus, the logarithmic arrangement of Equation (4) can be as follows:

$$LC_t = \tau_0 + \tau_1 LA_t + \tau_2 LN_t + \tau_3 LG_t + \tau_4 LY_t + \tau_5 LY_t^2 + \varepsilon_t \quad (3)$$

Estimation strategies

Testing at the unit root level can be used to opt whether or not swerving data ought to be introduced to deterministic time functions prior to regression on them to make the trends stationary. Sometimes, in economic and financial theory, it is assumed that non-stationary time series variables have some sort of long-term equilibrium relationship. Unit root testing in this work was done using three different methods: the Augmented Dickey-Fuller (ADF) test [58], the Dickey-Fuller generalized least squares (DF-GLS) test [59], and the Phillips-Perron (P-P) test [60]. The stationarity of the sample time series is tested using unit root tests. After checking for long-term trends in the study variables via long-run estimations, researchers turn their attention to the unit root features. This study uses the dynamic ordinary least squares (DOLS) technique provided by Stock and Watson [61] for the lengthier estimations. In addition, the FMOLS method for testing robustness, developed by Phillips and Hansen [62], is used in this investigation.
FMOLS and DOLS long-run estimations are consistent with many extensively applied econometric methods, as documented in the literature. In general, these methods excel in eliminating endogeneity issues in regressions and dealing with autocorrelation [61,62]. This analysis uses the DOLS and FMOLS models to estimate the long-run coefficient employing the following equation:

$$\Delta LC_t = \tau_0 + \tau_1 LC_{t-1} + \tau_2 LA_{t-1} + \tau_3 LN_{t-1} + \tau_4 LG_{t-1} + \tau_5 LY_{t-1} + \tau_6 LY_{t-1}^2 + \sum_{i=1}^{q} \gamma_1 \Delta LC_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LA_{t-i} + \sum_{i=1}^{q} \gamma_3 \Delta LN_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LG_{t-i} + \sum_{i=1}^{q} \gamma_5 \Delta LY_{t-i} + \sum_{i=1}^{q} \gamma_6 \Delta LY_{t-1}^2 + \varepsilon_t \quad (4)$$

where Δ is the first difference operator and q is the optimum lag length

Results and Discussion

The statistical results of many normality tests are also shown in Table 1. CO_2 emissions, alternative and nuclear energies, natural resources, government spending, and economic progression are all summarized. All these variables have a normal distribution, as seen by the high degree of concordance between their means, medians, maximums, and minimums. Data with a skewness close to zero are regularly distributed. All data were also shown to have a platykurtic distribution with less than three values, as shown by the results. In addition, the fact that Jarque-Bera has low values implies that the dataset follows a normal distribution.

Table 1. Summary statistics of the variables.

Variables	LC	LA	LN	LG	LY
Mean	12.75	3.81	-2.96	26.95	28.39
Median	12.77	3.80	-3.02	26.95	28.44
Maximum	12.85	3.91	-2.21	27.15	28.59
Minimum	12.49	3.64	-3.62	26.70	28.14
Std. Dev.	0.10	0.07	0.30	0.13	0.15
Skewness	-0.22	-0.58	0.20	-0.11	-0.48
Kurtosis	1.50	2.18	1.93	1.79	1.86
Jarque-Bera	1.53	1.89	0.22	2.01	2.36
Probability	0.79	0.68	0.90	0.37	0.43
Observations	32	32	32	32	32

The autoregressive unit root was determined using the ADF, DF-GLS, and P-P methods, all of which are based on the use of trends and constants. Results from our tests to identify the unit root are shown in Table 2. The variables were not level-stationary before the first difference was calculated, but all three unit root tests show that they are now stationary. Unit root tests show that the variables integrate in a first-difference fashion. There is no way to do a fraudulent regression analysis because all of the variables included in the empirical investigations tend toward their true values. To guarantee that no variable had a higher order of integration than the others, the unit root test favored the DOLS method over cointegration in this analysis.

Table 2. The outcomes of the unit root tests.

Variables		LC	LA	LN	LG	LY
ADF	Log levels	0.42	-2.08	-2.27	-1.59	-1.79
	Log first difference	-6.51***	-5.23***	-5.52***	-6.40***	-6.40***
DF-GLS	Log levels	0.21	-0.02	-1.01	0.51	0.12
	Log first difference	-4.10***	-5.19***	-4.75***	-3.80***	-6.41***
P-P	Log levels	1.13	-2.04	-2.23	-1.52	-1.67
	Log first difference	-6.51***	-6.08***	-11.61***	-6.45***	-6.40***

*** denotes significance at a 1% level

The unit root analysis of the data was used to estimate the long-run coefficient of the independent variables via DOLS regressions in this work. Table 3 shows the DOLS estimation outcomes. There is a negative link concerning the government's spending and CO_2 emissions, as well as the use of alternative and nuclear energy, natural resources, and transportation. CO_2 emissions, on the other hand, tend to go up when economies flourish. The EKC hypothesis holds in France because there is a negative correlation between the square of GDP and CO_2 emissions. This finding explains the significance of nuclear and renewable energy sources, as well as natural resources and public spending on consumption, to environmental sustainability. Sustainability in the natural world declines as economic development advances. Meanwhile, EKC has started making a good impact on the environment.

Based on the inverse relationship between the growth of the alternative and nuclear energy industry and the growth of France's CO_2 emissions, a 1% rise in the alternative and nuclear energy segment would result in a 0.46% reduction in France's CO_2 emissions. These findings agree with previous studies [11,12,19,26-28]. One of the key environmental issues with nuclear power is the formation of radioactive wastes like mill tailings, exploited reactor fuels, and additional radioactive pollutants involved with nuclear power generation. The stuffs could pose a risk to human health because they emit radiation for thousands of years. When in operation, nuclear power plants have no impact on air pollution or CO_2 emissions, in contrast to conventional power plants that rely on fossil fuels. However, a great deal of power is still needed for the mining, refining, and manufacturing of reactor fuel. Nuclear power plants use a great deal of energy in their production, as well as huge quantities of metal plus concrete. It is possible that the emissions from burning fossil fuels are linked to the electricity produced by nuclear power plants if fossil fuels are used in the mining and refining of uranium ore, or if fossil fuels are utilized in the construction of nuclear power stations.

Table 3. The results of DOLS estimation.

Variables	Coefficient	Standard error	t-statistic	p-value
LA	-0.46	0.09	-4.96	0.00
LN	-0.11	0.03	-3.98	0.00
LG	-0.50	0.11	-4.70	0.00
LY	1.28	0.30	4.25	0.00
LY^2	-0.30	0.07	-3.97	0.00
C	19.05	5.35	3.56	0.14
R^2	0.97			
Adjusted R^2	0.93			

Given the inverse rapport linking natural resources with CO_2 emissions, an expansion of 1% in natural resources might result in a 0.11% decrease in emissions or a 0.11% improvement in environmental sustainability in France. This research shows that the extraction, processing, and use of natural resources contribute to environmental issues like air, land, and water pollution, ecosystem destruction, and a loss of biodiversity. It's generally known that there are many types of environmental damage produced by the extraction, mining, exploration, and handling of natural resources. Deforestation, native species extinction, air, water, and land pollution, unstable soil and granite masses, desertification, and a changing climate are all instances of environmental disturbances [63,64]. Environmental degradation has led to the loss of a great deal of farmland, trees, and valuable cash crops. Since natural resources can't be gained without first being used, terribly harm initiated by their operation is also unavoidable. To lessen the impact of their exploitation, the government besides the natural resources sector should implement both preventative and corrective actions. The results of the present investigation are consistent with the previous studies [10,15,51,52].

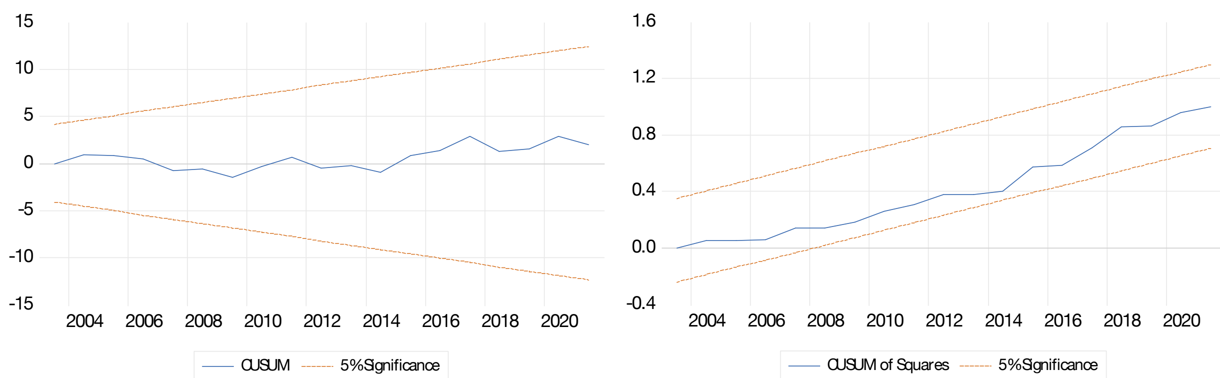
Since there is a negative connection between these two variables, a rise in government final consumption expenditures of 1% might lead to a 0.5% drop in France's CO_2 emissions. Many different types of government spending go into environmental protection. Government spending on environmental protection has been added to these existing headings. Science on environmental protection includes waste and management of wastewater, reduction of pollution, biodiversity and landscape preservation, and so on. This finding provides support for the idea that hydrocarbon windfalls, in addition to environmental levies and green programs, could be funded by the government. This means that handful of the most persistent ecological concerns may be resolved. This study also shows that money spent on environmental education and awareness programs by the government has the potential to raise people's standard of living and overall quality of life, both of which could aid in the promotion of environmental sustainability. The results of this investigation agree with those of previous studies [30,31,53,55-57].

The positive correlation between economic growth and CO_2 emissions suggests that an increase of 1% in economic growth might lead to a fall of 1.28% in France's environmental sustainability. This finding suggests that both environmental conservation and economic development are mutually dependent on one another. Natural resources on Earth put a cap on economic growth. The extent to which resources can be replaced, new technologies can be developed, and structural factors can shift can cause these boundaries to shift as well. Increasing economic activity has both beneficial and detrimental outcomes for the natural world, such as the uptick in the consumption of non-renewable resources, the acceleration of pollution and climate change, and the possible eradication of wildlife habitats. But not all expansions of the economy have the same impact on the natural world. Those in middle- and high-income societies see less environmental degradation as their incomes rise, and those in low-income cultures see more environmental degradation as their incomes rise. This indicates that increased population both contributes to and helps reduce air pollution. An increase of 1% in the square of economic growth is estimated to reduce CO_2 emissions by 0.30%, as indicated by the negative coefficient

estimate of the square of economic progress. Over time, a U-shaped link between per capita income and pollutants is predicted by the EKC hypothesis, which is supported by mounting evidence. Environmental pressure increases with income up to a certain degree and then decreases. The present study's result is consistent with the previous studies [16,19,22], that confirmed the existence of EKC in France.
Both theory and practice agree with the analysis's predicted coefficients. With an R^2 of 0.97 and an adjusted R^2 of 0.93, the evaluated regression model appears to be a good fit for the data. If that's the case, then shifts in the independent variables might explain around 93% of the variation in the reliant variable. This analysis verifies the reliability of the cointegration analysis by testing for normalcy, heteroscedasticity, and serial correlation. The compiled diagnostic test results are shown in Table 4. The data are normally distributed and there is no evidence of autocorrelation or heteroscedasticity in the model. The resilience of the model to recursive modifications was tested using the CUSUM and CUSUMQ procedures. At the 5% level of significance, the CUSUM and CUSUMQ diagrams are shown in Figure 2. The residual values are shown in blue, while the confidence intervals are shown in red. The model is considered stable at the 5% level if the confidence intervals for the examined residuals agree with the estimated values.

Table 4. The findings of the diagnostic tests.

Diagnostic tests	Coefficient	p-value	Decision
Jarque-Bera test	1.84	0.33	Residuals are normally distributed
Breusch-Godfrey LM test	1.15	0.22	No serial correlation exists
Breusch-Pagan-Godfrey test	1.62	0.36	No heteroscedasticity exists
Ramsey RESET test	1.84	0.40	The model is properly specified



(a) CUSUM plot (b) CUSUMQ plot

Figure 2. Results of (a) CUSUM and (b) CUSUMQ tests.

The reliability of FMOLS-based DOLS estimates was analyzed in this work. Table 5 displays the model-specific FMOLS regression coefficients. In France, the FMOLS data support the negative link predicted by DOLS between the government spending and CO_2 emissions from the usage of alternative and nuclear energies, natural resources, and transportation. The FMOLS estimates that France's CO_2 emissions can be lowered by 0.47% if the alternative and nuclear energy sector grows by just 1 percent. Furthermore, the FMOLS predicts that a 1% rise in natural resource exploitation might lead to a 0.12% drop in France's CO_2 emissions. France's CO_2 emissions might be cut by 0.51 percent if the government spent an additional 1 percent on consumers' final goods and services. Both the positive correlation between GDP and CO_2 emissions and the inverse correlation between GDP squared and CO_2 emissions were confirmed by the FMOLS test findings. As a result, FMOLS estimation results in France corroborated the presence of EKC. The FMOLS and the DOLS both arrive at the same results using the same methods. When estimating with FMOLS, high R^2, and adjusted R^2 values suggest that the components are well-fitting, explaining around 95% of the variation in the dependent variable.

Table 5. The results of FMOLS estimation.

Variables	Coefficient	Standard error	t-Statistic	p-value
LA	-0.47	0.10	-4.94	0.00
LN	-0.12	0.03	-4.13	0.00
LG	-0.51	0.09	-5.57	0.00
LY	1.48	0.26	5.61	0.00
LY^2	-0.33	0.06	-5.31	0.00
C	23.60	5.92	3.99	0.13
R^2	0.97			
Adjusted R^2	0.95			

Most European countries, including France, import the vast majority of their oil, natural gas, and coal needs to alleviate their energy poverty. To reduce reliance on imported fossil fuels and increase energy security, the government has increased investment in alternative and nuclear energy. Sustainable resources are those that can keep businesses running without jeopardizing the environment or the energy demands of future generations. A renewable energy source does not cause long-term damage to the environment and can be regenerated within a human lifespan. Sustainable energy sources include the sun, the wind, the waves, biomass, geothermal heat, and hydropower. Wind, sun, and hydropower are all examples of renewable energy. Conservation of natural resources and defense of global ecosystems are at the heart of sustainable environmental management, which aims to ensure people's well-being both now and in the future. Long-term ecosystem health is one indicator of environmental sustainability. The long-term health and productivity of resources can be ensured in part by safeguarding food supplies, farmlands, and fishing stocks.

Conclusion and Policy Recommendations

This research applies the EKC to a study of the environmental sustainability of France from 1990 to 2021, focusing on the impacts of alternative energy usage, natural resources, and government spending. All variables are converted to their natural logarithms before being used in the estimating process. To assess the effects of independent variables over the long run, the study uses the DOLS and FMOLS methods of cointegration regression. There is a negative link involving the government spending with CO_2 emissions, as well as the use of alternative and nuclear energies, natural resources, and transportation. In contrast, rising GDP and CO_2 emissions go hand in hand. The square of economic growth and CO_2 emissions in France have a negative association, supporting the EKC hypothesis. This finding explains the significance of nuclear and renewable energy sources, as well as natural resources and public spending on consumption, to environmental sustainability. Sustainability in the natural world declines as economic development advances. Meanwhile, EKC has started making a good impact on the environment.

The UN projects that by the year 2030, all people will have access to advanced energy services. Both energy efficiency and the share of renewable energy in the global energy matrix will increase by a factor of two. These goals are lofty, to say the least. The difficulty lies in the fact that few nations have created rules and regulations that will encourage a sustainable energy system. These will supply the necessary long-term, low-cost, and safe energy for these objectives. French officials might use these findings to craft measures to curb both nuclear waste and CO_2 emissions. Carbon emission reductions from nuclear and renewable energy sources in France are clarified by long-term projections. Nuclear power helps reduce pollution and cut down on GHG emissions. Natural gas does not appear to cut emissions, unlike nuclear and renewable energy. GHG emissions have been lowered thanks to both FDI and nuclear power. Nuclear energy's effect on both types of carbon emissions should be taken into account by policy analysts. Nuclear power has the dual benefit of both fulfilling growing energy demands and decreasing dependency on foreign sources of power. France's high nuclear energy production may be linked to higher total energy costs and CO_2 emissions. Additionally, nuclear energy may aid in achieving sustainable development goals and enhancing environmental measures. More money needs to be put towards nuclear energy in France. Economic growth, as well as improvements in social and environmental conditions, will result from a society that embraces nuclear technology. Nuclear energy is cheaper than other forms of energy generation and provides energy security while also lowering pollution from traditional energy sources. Nuclear power would also lessen the need for imported fuel. Nuclear power's ability to cut down on GHG emissions is becoming more important as the world becomes smaller. By lowering barriers to cross-border trade, FDI, and tech transfer, globalization has the potential to boost nuclear energy's market dominance.

Achieving a healthy balance between societal benefits and environmental effects is essential when exploiting natural resources. The goal of natural resource policy is to equitably divide up these two factors. The foundation of biodiversity protection rests on the same worries. Protecting biodiversity is possible through a variety of property rights. There are always winners and losers in any request. Designing a functional property rights system is complicated by considerations of equitable distribution, the need for metrics to track progress, and deadlines for reaching objectives. Promoting equitable distributions is a challenge for any policy on the allocation of resources, but biodiversity policy raises unique challenges. Even if people from outside the area are concerned about threats to ecosystem services, any defensive measures taken will be ineffective unless they coincide with the goals of the local landowners. When everyone plays by the rules and follows the procedures, resources are protected effectively. Natural resource systems can be challenging to control due to the many loopholes that can be used to avoid compliance. Critics of the property rights system, who refuse to acknowledge its distributional effects, really work against its evolution into a new form. Lack of resources encourages rent-seeking, which weakens institutions. Less annual tree cutting and reforestation of previously cut areas are examples of sustainable techniques. Due to the increasing human population, we need to conserve natural resources like trees, precious metals, and water as rapidly as possible.

True GDP expansion is the gold standard for measuring economic progress. However, additional economic development indicators are necessary, such as higher levels of education, better infrastructure, poverty reduction, and higher quality medical care. Economic development policy could include working to better the state of the economy, to foster low inflation and healthy growth. Supply-side measures like privatization, deregulation, tax cuts, and less regulation are needed to entice private capital investment. If the economy is diversified away from agriculture, more money can be spent on public goods like schools, roads, and hospitals, all of which are good for the economy.

Funding: Not applicable.
Acknowledgement: Not applicable.
Conflict of interest: The author declares no conflict of interest.
Authors contributions: Asif Raihan contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Asif Raihan, Mohammad Ridwan, Shakil Ahmad, Sourav Karmakar, and Pramila Paul. All authors read and approved the final manuscript.
Data availability statement: All data generated and analyzed during this study are available here: https://databank.worldbank.org/source/world-development-indicators

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