

Analysis of the Effect of Selected Macroeconomic Variables on Carbon Emissions in Kenya

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Abstract

As nations strive to balance economic growth with environmental sustainability, it is important to understand the dynamic relationship between carbon emissions and key macroeconomic variables so as to design appropriate environmental policies. Despite the existence of an enormous literature examining the linkages between economic growth and carbon emissions in Kenya, only a few studies have included structural breaks in their analyses. This study, therefore, explores the relationship between carbon emissions and key macroeconomic variables in Kenya from 1990 to 2021 using the Autoregressive Distributed Lag (ARDL) model within the standard Environmental Kuznets Curve theoretical framework. The data were obtained from the World Banks' World Development Indicators and include variables such as per capita Gross Domestic Product (GDP), foreign direct investment, natural resource rent, urbanization, energy consumption, and trade openness. Stationarity was tested using the Augmented Dickey-Fuller and Philips-Perron tests, which indicate that the variables were first-difference stationary. The ARDL bounds test results indicate the existence of a long-run relationship among the variables. Per capita GDP, energy consumption, urbanization, trade openness, and the 2014 structural break had a long-run positive effect on carbon emissions. This study recommends the promotion of investment in renewable energy, enforcement of environmentally-friendly trade policies, and enhancing urban planning given their long-run positive effects on carbon emissions.

Categories: Climate Change, Sustainable Economic Development

Keywords: ardl, carbon emissions, kuznets curve, stationarity, trade openness

JEL Classifications: Q50, Q59, Q00, Q55, Q56, F18, N50, O13, O00, O10

Introduction

Greenhouse gas (GHG) emissions have sharply grown, which is a clear indication of deteriorating environmental quality with Aboagye attributing this escalation of environmental issues to human economic activity, which tends to have detrimental consequences on the ecosystem as a whole (Aboagye, 2019). Global warming, deforestation, and biodiversity loss are some of the pressing environmental challenges that have drawn a lot of attention since the Rio de Janeiro Earth Summit in 1992 (Zmami and Ben-Salha, 2020). These issues are now central to global sustainable development, particularly under the Sustainable Development Goals (SDGs), notably SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), and SDG 12 (Responsible Consumption and Production).

The Sustainable Development Goal 7 (SDG 7) seeks to ensure access to affordable, reliable, sustainable, and modern energy for all. International Energy Agency (IEA) indicates that reducing reliance on fossil fuels and transitioning to renewable energy sources such as solar, wind, hydro, and geothermal is critical in achieving this goal (IEA, 2022). As indicated by United Nations Environment Program (UNEP), SDG 12 seeks to promote sustainable consumption and production patterns, including energy efficiency, waste reduction, and resource use optimization, all of which contribute to reducing GHG emissions (UNEP, 2024). SDG 13, on the other hand, emphasizes the need for urgent action to combat climate change and its impacts by improving education, awareness, and institutional capacity for climate change mitigation, adaptation, and early warning (United Nations, 2015). Addressing carbon emissions is a key component of this goal, and it is directly linked to the commitments outlined in the Paris Agreement of 2015.

Following the 2015 Paris Agreement, which aims to limit the global average temperature rise to below 2°C above pre-industrial levels and pursue efforts to cap it at 1.5°C, there has been renewed urgency across nations to address GHG emissions and climate change mitigation (Balogh and Jámbo, 2017). Despite this global commitment, the recent decades of economic expansion has largely been driven by carbon-intensive industries, especially in emerging and developing economies. This has led to an excessive exploitation of natural

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resources, widespread deforestation, and degradation of ecosystems as well as loss of biodiversity. Notably, the relationship between economic growth and environmental degradation continues to manifest in the form of increased GHG emissions, particularly CO₂, which remains the largest contributor to anthropogenic climate change (Zmami and Ben-Salha, 2020).

The major component of GHG emissions is CO₂, which represents more than 70% of the global GHG emissions. Since 1990, GHG emissions have increased by 50% and by 35% since 2000. CO₂ emissions from energy use alone rose by 60% since 1990 and 41% since 2000 (OECD, 2020). In 2023, global GHG emissions reached a record high of 57.1 GtCO₂e, which represents a 1.3% increase from 2022 levels. The energy sector remains the largest contributor to GHG emissions at 68%, followed agriculture, industry, and waste at 18%, 9%, and 4%, respectively. Within the energy sector, electricity production contributed the most emissions globally at 15.1GtCO₂e followed by transport at 8.4GtCO₂e (UNEP, 2024).

As reported by European Commission, the six largest GHG emitters accounted for 63% of global GHG emissions in 2023 and composed of China, United States, India, European Union (EU-27), Russian Federation and Brazil. By contrast, least developed countries (LDCs) accounted for only 3%. The African Union (AU) on the other hand contributed only 6% with the LDCs contributing just 3%, yet they continue to be the most vulnerable to climate change impacts (Crippa et al., 2024).

The United Nations Framework Convention on Climate Change (UNFCCC) indicates South Africa as Africa's biggest CO₂ emitter. Its carbon emissions increased by 1.5% in 2019. It is Africa's most advanced economy and contributes about 33% of the continent's steadily rising air pollution from fossil fuel combustion, oxidation, and cement production. Other high emitters in Africa include Egypt, Nigeria, Algeria, Ethiopia, Morocco, Libya, and Angola (UNFCCC, 2020). In 2023, carbon emissions in South Africa were estimated at 397MtCO₂e, with Egypt, Algeria, Nigeria, Morocco, and Libya following with 249MtCO₂e, 180MtCO₂e, 128MtCO₂e, 70MtCO₂e, and 61MtCO₂e, respectively (The Global Economy, 2024).

In Kenya, emissions in tons per capita were estimated at 0.25 in the year 1990 compared to 0.35 in the year 2018. Forest area in a thousand square kilometers has declined reaching 36.1 in 2018 from 38.6 in 1990. Urbanization, one of the factors responsible for the increase in carbon emissions, was at 5% in 1990 and 4.1% in 2018 according to World Bank (World Bank, 2020). Generally, Kenya is a low emitter of GHGs as indicated by the 0.1% contribution to global GHGs emissions and just 0.03% cumulative contribution to global carbon emissions in 2018. In 2023, Kenya's contribution to global GHGs was estimated at 0.2% and at 0.06% for carbon emissions. The main sources of carbon emissions are electricity and heat production contributing 39%, followed by transport at 30% and industry at 12.8% (IEA, 2023).

According to Olivier and Peters (Olivier and Peters, 2020), the direct drivers of emissions are the combustion of coal, oil, and natural gas, which accounts for 88% of global emissions, with respective shares of 39%, 31% and 18% with an extra 4% from calcination in cement clinker production. As indicated by Global Carbon Capture and Storage (CCS) Institute (Global CCS Institute, 2019), emissions can be reduced significantly if countries switch to renewable energy sources such as hydropower, wind, solar, nuclear power and sustainably produced biofuels.

Panayotou (Panayotou, 2001) shows that the state of the environment is determined by the size of the economy, the sectoral structure of the economy, vintage of technology, demand for environmental amenities and their conservation, including environmental expenditures and their effectiveness. Empirical studies show that environmental degradation is associated with economic performance, increasing population, trade, foreign direct investment (FDI), urbanization, energy consumption among other factors. Such studies among others include those by Aboagye (Aboagye, 2019) in South Africa, Aboagye et al. (Aboagye et al., 2020) in Ghana, and Gürlük (Gürlük, 2011) on economic growth and trade interactions. Other similar studies are those of Zmami and Ben-Salha (Zmami and Ben-Salha, 2020) on determinants of carbon emissions in Gulf Cooperation Council (GCC) countries and Kwakwa et al. (Kwakwa et al., 2018) for the case of Tunisia, Musibau et al. (Musibau et al., 2021) and Charfeddine et al. (Charfeddine et al., 2018) for Nigeria and Qatar economies, respectively.

Some studies that found a positive link between economic growth and the environment include those of Aboagye (Aboagye, 2017) and Aboagye et al. (Aboagye et al., 2020) for Ghana. Also, Kwakwa et al. (Kwakwa et al., 2018) report a positive link between economic growth and the environment. Generally, Gross Domestic Product (GDP) has been rising both locally and globally. As per World Bank (WB) statistics, the global GDP growth rate for 2021 was estimated at 6.26% representing a 9.19% increase from 2020 (World Bank, 2022). According to Kenya National Bureau of Statistics (KNBS) estimates, Kenya's real GDP grew by 5.6% in 2023 compared to 4.9% in 2022. The positive growth was notable across most sectors of the economy with agriculture contributing 21.8% of the total GDP. The service and industry sectors contributed 61.3% and 16.9% to GDP, respectively (KNBS, 2024).

The degree of openness of the economy as measured by FDI and trade openness can exert positive or negative impacts on the environment. In most low income countries, development is accelerated using FDI from developed nations. Development is seen in the form of increase in production (GDP), expansion of markets, improvement in transport and communication, energy generation, mining

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and discovering new sources of resources, which leads to environmental degradation (Zmami and Ben-Salha, 2020).

In the Kenyan context, Oluwaseun (Oluwaseun, 2025) indicates that FDI does not only contribute to GDP growth and job creation but is also associated with heightened deforestation, energy consumption, and industrial waste, which in turn raises carbon emissions. Similarly, UNCTAD (UNCTAD, 2023) report indicates that while Kenya is experiencing an increase in green FDI, particularly in renewable energy, these investments are inadequate to counterbalance the emissions produced by the swiftly growing urban and industrial sectors.

Trade openness has long been seen as a driver of economic growth and development as it allows nations to access a wider range of goods and services, specialize based on comparative advantage, draw in FDI, and reap the benefits of technology transfers (Ohnsorge and Quaglietti, 2023). As indicated by the United Nations Economic Commission for Africa (UNECA), Kenya has made trade openness a key component of its growth strategy and has integrated itself into global value chains by joining regional trade blocs including the Common Market for Eastern and Southern Africa (COMESA), the East African Community (EAC), and the African Continental Free Trade Area (AfCFTA) (UNECA, 2021). Kenya is a signatory to a number of international and regional treaties and conventions on the environment, a number of which are trade related and covering environmental pollution and the depletion of natural resources (Mwatu et al., 2026).

Kenya has integrated several environmental sustainability policies into its trade framework. For instance, the National AfCFTA Implementation Strategy (2022-2027) and its subsequent Green Supplement focus on decarbonizing the coffee and tea value chains, which are vital to the country's export economy (United Nations Economic Commission for Africa, 2024). By promoting climate-smart agriculture and sustainable processing, Kenya aims to maintain a competitive edge in global markets that are increasingly demanding "green" certifications for agricultural imports. To align itself with the Green Customs Guide to Multilateral Environmental Agreements, Kenya has ensured its trade gateways do not facilitate the movement of products that violate global environmental treaties or local conservation. The Green Customs Initiative under the UNEP equips customs officers with the skills to monitor and regulate the trade of environmentally sensitive goods, such as hazardous chemicals and endangered species (UNEP, 2024). Under the Sustainable Waste Management Regulations, the National Environment Management Authority (NEMA) requires manufacturers and importers to account for the environmental lifecycle of their products (National Environment Management Authority, 2024).

Urbanization is a development activity which is associated with transformation and growth of urban areas into cities and involves rural-urban migration. Kenya's urban population increased from 19.6% in 2000 to over 30% in 2022 and is expected to surpass 50% by 2040 (KNBS, 2022). Urbanization stimulates energy consumption by increasing the demand for food and housing, change in land usage, strain on public utilities, increased demand for residential home appliances and urban transportation which translates to more carbon emissions (Shahbaz et al., 2018).

According to the IEA (IEA, 2022), the energy sector accounted for nearly 73% of global CO₂ emissions. In Kenya, energy use is dominated by biomass (68%), followed by petroleum (22%) and electricity (9%). According to the IEA, biomass, which comprises of wood fuel, charcoal and agricultural waste, meets the basic cooking and heating needs of rural areas, urban poor and the informal sector. Kenya's energy consumption grew at an average annual rate of 2.2% between 2010 and 2022 (IEA, 2023).

Natural resources such as forests, gas, oil, minerals, and coal contribute significantly to economic growth but can increase carbon emissions and environmental degradation (Sibanda et al., 2023). Deforestation from logging and charcoal production has notably worsened emissions in Kenya. It is therefore vital that the financial gains from resource extraction do not compromise environmental sustainability.

Problem Statement: GHG emissions, in particular CO₂, remain a central concern in the global climate discourse due to their direct link to human activities such as fossil fuel combustion, industrialization and land use changes. CO₂ alone accounts for over 70% of total greenhouse gas emissions and continues to rise globally. In 2023, global CO₂ emissions were estimated at 36.8 billion tonnes, marking a 1.1% increase from 2022 (Global Carbon Project, 2023). This rise is largely driven by continued reliance on non-renewable energy sources, increasing energy demand, and sustained economic growth in emerging economies. Although historically industrialized nations have been the primary emitters, current trends show that emerging economies are rapidly becoming significant contributors due to urbanization and deeper integration into international markets (World Bank, 2023). As a result, climate change poses an escalating threat to global sustainable development and complicates efforts to mitigate its impacts.

Kenya, like many developing nations, faces a complex challenge in balancing economic development with environmental sustainability. Although the country has committed to reducing emissions through its Nationally Determined Contributions (NDCs), its growing economy and expanding infrastructure continue to exert pressure on the environment. According to Peace and Ye (Peace and Ye, 2020), carbon emissions represent a negative externality where the environmental and social costs are not borne by the emitters, thereby exacerbating the problem.

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Despite growing concerns, there is limited empirical evidence on the macroeconomic factors influencing carbon emissions in Kenya. While global studies have identified variables such as GDP growth, population size, energy consumption, urbanization, foreign direct investment, trade openness, and natural resource rents as key drivers of emissions (Shahbaz, 2013), their specific impacts in the Kenyan context remain underexplored. This gap in knowledge limits the effectiveness of policy interventions. Therefore, this study seeks to identify and analyze the macroeconomic determinants of carbon emissions in Kenya. By doing so, it aims to contribute to the formulation of targeted, evidence-based policies that support Kenya's transition to a low-carbon development pathway, while safeguarding economic progress.

Research Method

Research design and variable description

This study adopted the longitudinal time series research design to examine the dynamic relationships among variables over time capturing both short-run adjustments and long-run equilibrium effects. This design is suitable for analyzing macroeconomic-environmental interactions since it accounts for historical patterns, cyclical fluctuations, and structural shifts that may shape carbon emissions. Using annual time series data for the period 1990-2021, the study examined the relationship between CO₂, which is the dependent variable and GDP per capita (GDPPC), FDI, trade openness (TR), energy consumption (EC), urbanization (URB), and natural resource rents (NRR). The study data was obtained from the World Bank's World Development Indicators (WDI) database (World Bank, 2022).

Carbon dioxide emissions are widely used in environmental economics as a key indicator of environmental degradation, especially in studies examining the relationship between the environment and macroeconomic variables. In the Kenyan context, major sources of CO₂ emissions include the energy, transport, and industrial sectors, which are closely tied to the country's development path. Shahbaz et al. (Shahbaz et al., 2018) emphasize that CO₂ emissions capture the environmental costs associated with economic growth, making them essential for policy analysis.

GDP per capita is widely used as a measure of economic development and is integral to testing the Environmental Kuznets Curve (EKC) hypothesis. Stern (Stern, 2004) and Dinda (Dinda, 2004) both emphasize the inclusion of GDP per capita in environmental models as a theoretical and empirical necessity. Energy consumption is a critical driver of CO₂ emissions, especially when a country is heavily reliant on fossil fuels (Sharma, 2011). Countries that depend on non-renewable energy sources tend to emit more GHGs. According to Ang (Ang, 2007), energy use and emissions maintain a strong long-run equilibrium. Similarly, Lotfalipour et al. (Lotfalipour et al., 2010) show that increasing energy consumption significantly drives carbon emissions in emerging economies.

Urbanization, which captures the demographic shift from rural to urban areas, influences energy demand, transportation, infrastructure, and land use, and can intensify or mitigate emissions depending on planning and energy sources. Parikh and Shukla (Parikh and Shukla, 1995) found that urbanization raises emissions due to increased energy-intensive consumption, while Fan et al. (Fan et al., 2006) highlight cases where urban agglomeration improves efficiency and reduces emissions.

Natural resource rents represent income from exploiting natural resources and can signify over-extraction or mismanagement if not well-governed. Natural resource rents play a critical role in shaping environmental outcomes particularly in countries where resource extraction contributes significantly to national income (Kwakwa et al., 2020). Empirical evidence suggests that in the absence of strong environmental regulations, higher resource rents are often linked to increased environmental degradation. For instance, Zuo et al. (Zuo et al., 2021) found that rising natural resource rents significantly increase the ecological footprint in resource-dependent economies, highlighting the environmental costs of extraction-led growth. Including natural resource rents in this study therefore allows for a better understanding of how resource-based income streams influence emissions.

Trade openness influences carbon emissions through the scale, technique, and composition effects. While trade can spread clean technologies, it may also exacerbate emissions if countries specialize in polluting industries. Antweiler et al. (Antweiler et al., 2001) and Cole (Cole, 2004) find that the impact of trade on emissions depends on the type of goods traded and environmental regulation strength.

FDI is included in the study due to its complex role in environmental outcomes. Mose et al. (Mose et al., 2024) show that FDI often increases CO₂ emissions, consistent with the pollution haven hypothesis, where lax environmental regulations attract pollution-intensive industries. However, under the pollution halo hypothesis, FDI can reduce emissions by introducing cleaner technologies and better environmental practices (Acheampong and Opoku, 2023). As Kenya continues to attract foreign investment, particularly in energy and manufacturing, examining FDI's impact is essential to understand whether it supports sustainable development or it exacerbates environmental degradation. Table 1 presents the study variables and their measurement.

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Category	Variable	Measurement
Dependent Variable	lnCO ₂ (Carbon Emissions)	Kilotons (kt)
Independent Variables	lnGDPPC (GDP per Capita)	GDP/Total population (Constant 2010 USD)
	lnFDI (Foreign Direct Investment)	Total inflows of FDI in million dollars
	TR (Trade Openness)	Ratio of total trade (exports + imports) to GDP
	NRR (Natural Resource Rent)	Total percentage of GDP associated with sales of natural resources
	lnEC (Energy Consumption)	Energy use (kg of oil equivalent per capita)
	lnURB (Urbanization)	Percent of total population in urban areas

TABLE 1: Description and measurement of variables

Data were obtained from World Banks World Development Indicators (WDI) Database. GDP, Gross Domestic Product; FDI, foreign direct investment.

The dependent variable was log-transformed (lnCO₂) to normalize the distribution and facilitate interpretation in terms of percentage changes. The independent variables are included in different functional forms based on their theoretical relevance, scale, and measurement characteristics. The use of these mixed functional forms ensures appropriate treatment of each variable while preserving meaningful and interpretable results within the log-linear modeling framework. Variables such as GDP per capita, energy consumption, urbanization, and FDI were used in natural logarithm form to allow elasticity-based interpretations, whereas TR was included in its ratio form rather than as a logarithm so as to allow for a more intuitive interpretation. The coefficient reflects the percentage change in CO₂ emissions resulting from a one-unit increase in TR (Wooldridge, 2016).

Theoretical framework

This study adopts the EKC theory, which posits an inverse U-shaped relationship between income levels and environmental degradation (Grossman and Krueger, 1991). Initially, environmental quality declines with rising income, but after a certain threshold, it improves (Mäler, 2013). This dynamic operates through three mechanisms: scale, composition, and technological effects.

The scale effect suggests that economic growth increases resource extraction and emissions, worsening environmental quality (Gürlük, 2011). The composition effect refers to structural changes in the economy - early development is marked by pollution-intensive sectors like agriculture and industry, while higher income levels shift activity toward cleaner sectors such as services and knowledge-based industries. The technological effect reflects how innovation, often driven by research and development and FDI, leads to cleaner production methods and reduced pollution (Gürlük, 2011).

Econometric procedures

To ensure validity, diagnostic tests were conducted, including unit root tests for stationarity and cointegration analysis to assess long-run relationships. Lag length selection criteria - Akaike Information Criterion (AIC), Schwarz criterion (SIC) and Hannan-Quinn Information Criterion (HQIC) - were used to determine the optimal lag structure, while structural break tests were included to identify key policy or economic shocks. The econometric model used for the analysis is the Autoregressive Distributed Lag (ARDL) model. A brief description of the procedures is discussed as follows:

Unit root tests: Given that many economic time series often contain unit roots, they require transformations such as differencing to achieve stationarity and avoid spurious regressions (Musibau et al., 2021). This study employed the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Clemente-Montanes-Reyes (CMR) tests to determine the order of integration and account for structural breaks.

For ADF test the following equation was estimated for each of the time series:

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$$\Delta Y_t = \alpha_0 + \beta_0 T + \gamma Y_{t-1} + \sum_{i=1}^k \alpha_1 \Delta Y_{t-i} + \varepsilon_t \quad (1)$$

In the equation, Y represents each of the variables, β is the coefficient on time trend T , $Y_{(t-i)}$ represents lagged values for the variables, and k is the lag length. The lag length is set by use of AIC, HQIC, and Schwartz Bayesian Information Criterion (SBIC). The unit root tests are done for each variable independently to determine whether a variable is stationary or not thus the ADF tests the null hypothesis: H_0 : That the variable in question contains a unit root (non-stationary) against the alternative: H_1 : That the variable in question does not contain a unit root (stationary).

The Phillips Perron (PP) unit root test modifies the ADF test to accommodate serial correlation. The null hypothesis is that the variable in question contains a unit root (non-stationary) against the hypothesis that the variable in question has no unit root (stationary). It involves fitting the regression:

$$y_i = \alpha + \rho y_{i-1} + \varepsilon_i \quad (2)$$

Ng and Perron (Ng and Perron, 1995) argue that PP test statistics can be viewed as Dickey-Fuller statistics that have been made robust to serial correlation by using the Newey-West heteroskedasticity and autocorrelation-consistent covariance matrix estimator.

Structural breaks analysis: In time series analysis, stationarity assumes constant mean, variance, and covariance over time (Clemente et al., 1998). Structural breaks can violate this assumption, leading to misleading results. The CMR test examines whether a series has a unit root with two structural breaks (null) or is stationary with two breaks (alternative). It captures sudden or gradual changes in the series mean using the additive outlier (AO) model for abrupt shifts or the innovational outlier (IO) model for gradual shifts.

Taking an autoregressive structure of AR (1) with drift, the AO is specified as:

$$y_t = \mu + \delta I_t[t = T_{AO}] + z_t; \quad z_t = \phi z_{t-1} + \varepsilon_t \quad (3)$$

Where $I_t[\cdot]$ is an indicator dummy variable observed for $t = 1, 2, \dots, T$. It takes a value of 1 when $t = T_{AO}$ and zero otherwise. The time series z_t is the uncontaminated but unobserved time series while y_t is the observed time series and δ is the size of the outlier.

The IO on the other hand is a type of observation where the outlier has its origin in the underlying noise process. Assuming an AR (1) structure with drift, innovational outlier (IO) model is specified as:

$$y_t = \mu + \frac{1}{1 - \rho L} \delta I_t[t = T_{IO}] + z_t; \quad z_t = \rho z_{t-1} + \varepsilon_t \quad (4)$$

The behavior of y_t series depends on the autoregressive structure of z_t and the IO affects the T_{IO}^{th} observation by δ and affects the subsequent observations by $\rho^{(t-T_{IO})}\delta$.

The double break AO model is thus a two-step procedure with the first step involving the estimation of the following equation:

$$y_t = \mu + \delta_1 DU_{1t} + \delta_2 DU_{2t} + \tilde{y}_t \quad (5)$$

Where DU is mean shift for a break variable and is equal to 1 for $t \geq T_{bm}$ and 0 otherwise under a null hypothesis of unit root for $m = 1, 2$ and T_{b1} and T_{b2} are the breakpoints resulting from the shifts in the mean. The residuals from equation 1 are then regressed on their lagged values, a number of lagged differences and a set of dummy variables. Thus, we have:

$$\tilde{y}_t = \sum_{i=1}^k w_{1i} DT_{(b1,t-i)} + \sum_{i=1}^k w_{2i} DT_{(b2,t-i)} + \alpha \tilde{y}_{t-i} + \sum_{i=1}^k \theta_i \Delta \tilde{y}_{t-i} + l_i \quad (6)$$

Where DT is trend shift and $DT_{(bm,t)}$ takes the value of 1 for $t = T_{bm} + 1$ and 0 otherwise for $m = 1, 2$. Equation (6) is estimated over feasible pairs of T_{b1} and T_{b2} searching for the minimal t-ratio for the null hypothesis $\alpha = 1$. The null hypothesis is that the series has a unit root with structural breaks $H_0 : \alpha = 1$ against the alternative hypothesis that they are stationary with structural breaks $H_1 : \alpha < 1$.

The IO variant of model 2 is expressed as:

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$$y_t = \mu + \delta_1 DU_{1t} + \delta_2 DU_{2t} + \Phi_1 DT_{(b1,t)} + \Phi_2 DT_{(b2,t)} + \alpha y_{t-i} + \sum_{i=1}^k \theta_i \Delta y_{t-i} + l_t \quad (7)$$

An estimate of α significantly less than unity provides evidence against the null hypothesis of presence of unit root with structural breaks.

Empirical model: ARDL model

Theoretical Model: Studies concerned with how economic activity affects the environment have utilized the IPAT model. According to the IPAT model, environmental effect I is the product of three factors Population (P), Affluence (A), and technological advancement (T) (Ehrlich and Holdren, 1971). This relationship is represented as:

$$I = PAT \quad (8)$$

Where I is influence, P is demographics, A is economic growth, and T is technological considerations. Dietz and Rosa (Dietz and Rosa, 1971) extended the IPAT model to Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) to allow for hypothesis testing since within the IPAT model it is not possible to carry out hypothesis testing. This is specified as:

$$I_t = \alpha P_t^b A_t^c T_t^d \varepsilon_t \quad (9)$$

The linearized form of the model is specified as:

$$[\ln I]_t = \alpha + [b \ln P]_t + [c \ln A]_t + [d \ln T]_t + \varepsilon_t \quad (10)$$

Where α is the intercept term, b, c, d are the coefficients to be estimated, ε is the error term and t is the time. The STIRPAT model makes it possible to evaluate the impact of various factors on carbon emissions. In this study, carbon emissions represent influence, whereas GDP per capita represents affluence. The extended form of the theoretical model is specified as:

$$[\ln CO]_{2t} = \beta_0 + \beta_1 [\ln GDPPC]_t + \beta_2 \ln FDI + \beta_3 [\ln EC]_t + \beta_4 [TR]_t + \beta_5 [\ln URB]_t + \beta_6 [NRR]_t + \varepsilon_t \quad (11)$$

Where β_0 is the intercept term, β_i s are the coefficients of the explanatory variables, GDPPC is per capita GDP, FDI is Foreign Direct Investment, EC is Energy Consumption, TR is Trade Openness, URB is Urbanization, NRR is Natural Resource Rents, ε is the error term and t is time.

From the empirical model, the ARDL model is generated. The ARDL model makes it possible to analyze the short-run and long-run relationship among the dependent and independent variables (Pesaran and Shin, 1998). Similarly, the model generates efficient and consistent results even with small sample data. The model is specified as:

$$\begin{aligned} \Delta \ln CO_{2t} = & \gamma_0 + \gamma_1 \ln CO_{2(t-1)} + \gamma_2 \ln GDPPC_{(t-1)} + \gamma_3 \ln FDI + \gamma_4 TR_{(t-1)} + \gamma_5 \ln EC_{(t-1)} \\ & + \gamma_6 \ln URB_{(t-1)} + \gamma_7 NRR_{(t-1)} + \gamma_{Dum} TBK_t \\ & + \sum_{i=1}^{n_1} \lambda_{1i} \Delta \ln CO_{2(t-i)} + \sum_{i=0}^{n_2} \lambda_{2i} \Delta \ln GDPPC_{(t-i)} + \sum_{i=0}^{n_3} \lambda_{3i} \Delta \ln FDI \\ & + \sum_{i=0}^{n_4} \lambda_{4i} \Delta \ln EC_{(t-i)} + \sum_{i=0}^{n_5} \lambda_{5i} \Delta TR_{(t-i)} + \sum_{i=0}^{n_6} \lambda_{6i} \Delta \ln URB_{(t-i)} \\ & + \sum_{i=0}^{n_7} \lambda_{7i} \Delta NRR_{(t-i)} + \varepsilon_t \end{aligned} \quad (12)$$

Where Δ is the first difference operator, γ_0 is the intercept term, TBK represents a dummy variable to capture any structural breaks, $\lambda_{(1,...,7)}$ are the short-run coefficients and $\gamma_{(1,...,7)}$ are the long-run coefficients and all other variables are as previously defined. Testing for cointegration is done under the null and alternative hypotheses:

$H_0 : \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = \gamma_6 = \gamma_7 = 0$ (No cointegration)

$H_1 : \gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq \gamma_5 \neq \gamma_6 \neq \gamma_7 \neq 0$ or

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H_1 : At least one $\gamma_i \neq 0$, $i = 1, \dots, 7$ (Cointegration exists)

The computed F-statistic is compared to Narayan ([Narayan, 2005](#)) critical bounds. If it exceeds the upper bound, the null of no co-integration is rejected but if it falls below the lower bound, the null is not rejected and only the short-run ARDL model is specified.

Results And Discussion

Descriptive statistics

The time series data are composed of 32 annual observations with the dependent variables being Carbon Emissions (Kilotons). The independent variables include per capita Gross Domestic Product (Constant 2015 USD), Energy Consumption (kg of oil equivalent per capita), Urbanization (percent of total population), Natural Resource Rent (percent of GDP), Trade Openness (ratio of exports and imports to GDP), and Foreign Direct Investment (total inflows in million USD). The results for the descriptive statistics are presented in Table 2.

Variable	Mean	Std. Dev.	Median	Max	Min	Skewness	Kurtosis	JB	p-value
CO ₂	11170.65	5471.068	8810	23044.86	5860	0.89	2.471	4.599	0.1003
GDP	5.09E+10	1.87E+10	4.52E+10	9.04E+10	3.04E+10	0.656	2.112	3.345	0.1878
GDPPC	1336.918	158.509	1276.272	1704.967	1165.166	0.918	2.575	4.731	0.0939
EC	493.192	40.652	480.623	586.167	448.099	0.718	2.25	3.498	0.174
URB	22.113	3.53	21.86	28.493	16.748	0.189	1.85	1.953	0.3766
NRR	3.662	1.582	3.291	7.286	1.202	0.433	2.666	1.148	0.5631
TR	0.351	0.058	0.344	0.456	0.239	-0.005	2.362	0.5424	0.7625
FDI	317.109	193.553	293.222	696.938	53.656	0.351	1.966	2.082	0.3531

TABLE 2: Descriptive Statistics

The results indicate that all the variables are platykurtic as their Kurtosis values are less than three ($K < 3$). The skewness for all the variables is less than 1, which shows that the variables are moderately skewed. The Jarque-Bera normality test results show that all the variables conform to normality test.

Unit root analysis

The results for ADF and PP unit root test are as shown in Table 3 both for intercept and intercept and trend. The results indicate that all variables are first difference stationary at 5% level of significance.

		ADF		PP		Conclusion
		T	P value	T	P value	
CO ₂	Intercept	1.743	0.9982	2.522	0.9991	N
	First Diff	-4.191	0.0007	-6.517	0.0000	S
	I&T	0.975	0.9474	-1.080	0.9324	N
	First Diff	-5.506	0.0000	-8.840	0.0000	S
GDPPC	Intercept	2.054	0.9987	1.924	0.9986	N
	First Diff	-3.829	0.0026	-3.780	0.0031	S
	I&T	-1.525	0.8205	-1.539	0.8152	N
	First Diff	-5.718	0.0000	-5.850	0.0000	S
EC	Intercept	-0.373	0.9145	0.556	0.9865	N
	First Diff	-6.431	0.0000	-7.025	0.0031	S
	I&T	-3.221	0.0803	-3.031	0.1237	N
	First Diff	-6.454	0.0000	-7.312	0.0000	S
URB	Intercept	0.414	0.9820	0.395	0.9813	N
	First Diff	-5.385	0.0000	-5.387	0.0000	S
	I&T	-1.071	0.9338	-1.253	0.8991	N
	First Diff	-5.468	0.0000	-5.542	0.0000	S
NRR	Intercept	-0.862	0.8003	-0.840	0.8072	N
	First Diff	-6.054	0.0000	-6.064	0.0000	S
	Trend	-3.111	0.1037	-3.191	0.0862	N
	First Diff	-5.981	0.0000	-5.988	0.0000	S
TR	Intercept	-1.846	0.3578	-1.858	0.3521	N
	First Diff	-4.843	0.0000	-4.860	0.0000	S
	I&T	-1.019	0.9415	-1.018	0.9417	N
	First Diff	-5.323	0.0001	-5.314	0.0001	S
FDI	Intercept	-2.231	0.1952	-2.010	0.2824	N
	First Diff	-7.063	0.0000	-8.233	0.0000	S

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Analysis of the Effect of Selected Macroeconomic Variables on Carbon Emissions in Kenya

	I&T	-3.439	0.0464	-3.350	0.0585	S/N
	First Diff	-6.943	0.0000	-8.062	0.0000	S

TABLE 3: ADF and PP unit root tests

ADF, Augmented Dickey Fuller; PP, Philips-Perron; S, Stationary (Does not contain a unit root); N, Not stationary (Contains unit root); S/N, Stationary under ADF and not stationary under PP; I&T, Intercept and Trend; First Diff, First Difference

Tables 3 and 4 show Clemente-Montanes-Reyes test results for AO and IO models. This study adopts the IO model, which assumes gradual structural changes with breaks in both slope and intercept. All variables were first difference stationary under IO, except FDI, which was level stationary. In the AO model, energy consumption was level stationary, while GDP per capita was non-stationary at both levels.

Variable	Test Statistic	Level SB1	SB2	Conclusion	Test Statistic	First Diff. SB1	SB2	Conclusion
CO ₂	-3.441	2006(0.000)	2013(0.000)	Not stationary	-6.542	2001(0.420)	2010(0.463)	Stationary
GDPPC	-3.247	2008(0.000)	2015(0.000)	Not stationary	-4.645	2004(0.044)	2006(0.722)	Not stationary
EC	-5.772	1998(0.001)	2010(0.000)	Stationary	-	-	-	-
URB	-2.995	2005(0.000)	2014(0.000)	Not stationary	-5.92	2005(0.358)	2014(0.319)	Stationary
NRR	-3.013	1993(0.058)	2007(0.000)	Not stationary	-6.651	1993(0.027)	2001(0.210)	Stationary
TR	-3.549	2005(0.000)	2015(0.000)	Not stationary	-6.225	2004(0.606)	2012(0.042)	Stationary
FDI	-2.833	2004(0.145)	2008(0.005)	Not stationary	-8.067	2005(0.869)	2009(0.964)	Stationary

TABLE 4: Clemente-Montañes-Reyes additive outliers unit root results

* H0: The series are not stationary with structural breaks and H1: The series are stationary with break. SB1 and SB2 denote the structural break dates, and values in brackets are the p-values for respective break dates. The critical value at 5% is -5.490.

In the IO model, the assumption is that structural changes take place gradually and allows for a break in both the slope and the intercept of the model.

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Variable	Test Statistic	Level SB1	SB2	Conclusion	Test Statistic	First Diff. SB1	SB2	Conclusion
CO ₂	-0.827	2002(0.044)	2014(0.121)	Not stationary	-6.327	2007(0.020)	2018(0.477)	Stationary
GDPPC	-2.319	2008(0.001)	2016(0.064)	Not stationary	-5.772	2001(0.035)	2008(0.169)	Stationary
EC	-3.342	1998(0.009)	2010(0.002)	Not stationary	-7.813	2009(0.021)	2012(0.077)	Stationary
URB	-3.048	2004(0.008)	2013(0.011)	Not stationary	-6.193	1993(0.006)	2006(0.001)	Stationary
NRR	-3.013	1993(0.058)	2007(0.000)	Not stationary	-6.651	1993(0.027)	2001(0.210)	Stationary
TR	-3.627	2003(0.004)	2013(0.001)	Not stationary	-6.432	1995(0.012)	2013(0.001)	Stationary
FDI	-24.783	2006(0.145)	2009(0.005)	Stationary	-	-	-	-

TABLE 5: Clemente-Montañes-Reyes innovative outliers unit root test results

In the IO model, the assumption is that structural changes take place gradually and allows for a break in both the slope and the intercept of the model.

The IO results in Table 5 show that all variables are stationary at first difference, except FDI, which is stationary at level. Structural breaks identified in the data correspond to significant political, economic, and policy events. In 2002, a structural break in CO₂ emissions coincided with a peaceful political transition, which spurred industrial growth and led to higher emissions (UNFCCC, 2021). Another break in 2014 aligned with the implementation of Vision 2030 infrastructure projects that increased industrial activity and urbanization (KNBS, 2023).

GDP per capita exhibited breaks in 2008 and 2016. The 2008 shift reflects disruptions from post-election violence, while the 2016 break captures economic recovery through Vision 2030. For energy consumption, structural breaks in 1998 and 2010 highlight shifts in the energy mix. The 1998 reform liberalized the oil sector, increasing petroleum use, while the 2010 break reflects growing environmental concerns (Saungweme and Odhiambo, 2021).

Urbanization showed structural breaks in 2004 and 2013. The 2004 break is linked to economic liberalization and rural-urban migration, while the 2013 break reflects urban growth driven by devolution under the new constitution (ADB, 2022) (KNBS, 2023). Trade openness exhibited breaks in 2003 and 2013, coinciding with post-2002 economic recovery as well as deeper EAC integration and Chinese trade relations by 2013. FDI breaks in 2006 and 2009 reflect institutional reforms by KenInvest and the impact of the 2007-2008 global financial crisis, respectively (World Bank, 2022) (Saungweme and Odhiambo, 2021).

Analysis of cointegration: Since the variables are integrated of the same order as shown by Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, the study established that the ARDL model is applicable. Since annual data is used, an initial maximum lag of 2 is used for ARDL estimation. Table 6 presents the results for the ARDL bounds test for cointegration.

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Statistic/Level	I(0)	I(1)
F-statistic	5.194	-
Critical Value (10%)	1.7	2.83
Critical Value (5%)	1.97	3.18
Critical Value (1%)	2.54	3.91

TABLE 6: ARDL bounds test for cointegration

Note: I(0) and I(1) are lower bound and upper bound critical values**, respectively**. H_0 states that there is no level relationship among the variables. H_0 is accepted if the F-statistic is less than the lower bound critical value I(0), and H_0 is rejected if the F-statistic is greater than the upper bound critical value I(1). ARDL, Autoregressive Distributed Lag

The value of the F-statistic (5.194) falls above the upper bounds I(1) critical value of 3.180 hence the null hypothesis of no level relationship is rejected. This leads to the estimation of short-run and long-run estimates using the ARDL regression model as presented in Table 7.

Section	Variable	Coef.	Std. Err.	T	P>t
Model Info	lnCO ₂	lnGDPPC lnEC NRR lnURB TR lnFDI DUM2002 DUM2014 ARDL(1,1,1,1,1,1,0,0)			
Model Info	Number of obs	31			
Model Info	Sample	1991–2021			
Model Info	R-squared	0.9324			
Model Info	Adj R-squared	0.8648			
Long Run	lnGDPPC	2.078	0.243	8.56	0
Long Run	lnEC	0.803	0.3	2.68	0.017
Long Run	NRR	-0.024	0.01	-2.54	0.023
Long Run	lnURB	0.045	0.011	4.12	0.001
Long Run	TR	3.071	0.386	7.95	0
Long Run	lnFDI	-0.164	0.026	-6.35	0
Long Run	DUM2002	-0.083	0.026	-3.17	0.006
Long Run	DUM2014	0.228	0.044	5.13	0
Short Run	Constant	-12.689	2.536	-5	0
Short Run	ΔlnGDPPC	-2.987	0.452	-6.61	0
Short Run	ΔlnEC	0.716	0.284	2.52	0.024
Short Run	ΔNRR	0.011	0.011	1.03	0.318
Short Run	ΔlnURB	-0.101	0.039	-2.56	0.022
Short Run	ΔTR	-1.142	0.346	-3.3	0.005
Short Run	ΔlnFDI	0.123	0.016	7.55	0
Short Run	Trend	-0.0032	0.024	-0.13	0.895
Short Run	ECT(-1)	-0.811	0.19	-4.26	0.001
Diagnostics	Durbin-Watson	2.132			
Diagnostics	Ramsey RESET F-statistic	0.19		0.8998	
Diagnostics	Breusch-Godfrey LM test	1.541		0.2145	

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Diagnostics	Breusch-Pagan / Cook-Weisberg	0.49		0.4826	
Diagnostics	Jarque-Bera	3.07		0.2154	

TABLE 7: ARDL regression results

ARDL, Autoregressive Distributed Lag

Long-run estimates: In the long run, all variables are significant in explaining carbon emissions. Income as measured by the log of GDP Per capita (lnGDPPC) exerts a positive and significant impact on carbon emissions in the long run. Specifically, a 1% increase in GDPPC leads to approximately a 2.078% increase in carbon emissions in the long run. This finding implies that economic expansion in Kenya is energy-intensive and reliant on carbon-emitting activities, and in the absence of strong environmental regulations and clean technologies, this leads to increased emissions. This result complies with that of Aboagye et al. (Aboagye et al., 2020) and Kwakwa et al. (Kwakwa et al., 2018) for the case of Ghana, Mesagan and Nwachukwu (Mesagan and Nwachukwu, 2018) for Nigeria, Kibria et al. (Kibria et al., 2021) for South Asia. However, Powanga and Kwakwa (Powanga and Kwakwa, 2024) present contrary results, since their study reported that income (GDP) is associated with reductions in carbon emissions both in the long run.

The results indicate that energy consumption has a positive and significant impact on carbon emissions. Specifically, a 1% increase in energy consumption leads to approximately a 0.803% increase in carbon emissions. This result suggests that Kenya's energy use remains largely reliant on carbon-intensive sources, hence a higher energy demand translates directly into increased carbon emissions in the long run. These impacts are intensified in low-income settings where technological and regulatory capacities are limited, and clean alternatives remain unaffordable or inaccessible. These results are in line with that of Aboagye (Aboagye, 2017) and Chontanawat (Chontanawat, 2020) who found a positive relationship between energy consumption and environmental degradation in Ghana and ASEAN countries, respectively.

Urbanization has a positive and significant impact on carbon emissions in the long run. Specifically, a 1% increase in urbanization leads to a 0.045% increase in carbon emissions. This suggests that rapid urban growth is associated with increased environmental pressure, likely driven by higher energy demand, transport emissions, and expansion of infrastructure in urban areas, thereby contributing to environmental degradation over time. As a larger proportion of the population moves to urban areas, challenges associated with heavy vehicular traffic, clearing of vegetation cover to put in place infrastructure, and increased waste generation result in decreased environmental quality (Kwakwa et al., 2018).

For NRR, a one percentage point increase leads to a 0.024% decrease in carbon emissions. Though it is expected that natural resource extraction increases destruction of the environment, it may not be the case sometimes if the returns from resources are used to protect the environment and if non-polluting and environmentally friendly techniques are used in extraction process. This result suggests that a higher contribution of natural resource-based activities to GDP in Kenya is associated with lower emissions, which may reflect relatively less carbon-intensive resource sectors, improved resource management practices or efficiency gains in extraction processes over time. These results are supported by those of Tufail et al. (Tufail et al., 2021) for OECD countries who found that natural resources rent improve the atmosphere by reducing CO₂ emissions. However, it is at variance with that of Aboagye et al. (Aboagye et al., 2020) and Aboagye (Aboagye, 2017) for Ghana who report that natural resource rents increase carbon emissions in the long run but reduce in the short run.

Trade openness has a positive and significant impact on carbon emissions in the long run. The results show that a 1 percentage point increase in trade openness leads to 3.071% increase in carbon emissions. This emphasizes the fact that trade has negative impacts on environment through trading and transportation of goods or through production in areas with lower environmental standards. This result also suggests that greater integration into international trade is associated with higher emissions in Kenya, likely due to increased production for export markets, expansion of industrial activity, and reliance on energy-intensive production processes that elevate environmental degradation over time. These findings are consistent with that of Al-mulali et al. (Al-mulali et al., 2015) in Kenya, OECD, (OECD, 2017), Balogh and Jambor (Balogh and Jambor, 2017) for South Africa. However it is at variance with the results of Shahbaz (Shahbaz, 2013) for South Africa.

FDI has a negative and significant impact on carbon emissions in the long run. Specifically, a 1% increase in FDI leads to a 0.164% decrease in carbon emissions. This suggests that in the long run, FDI inflows in Kenya are associated with improved environmental outcomes, possibly due to introduction of cleaner technologies, more efficient production processes and improved environmental

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management practices, consistent with the Pollution Halo hypothesis. This outcome complies with that of Aboagye et al. (Aboagye et al., 2020) for Ghana, Odugbesan and Adebayo (Odugbesan and Adebayo, 2020) for Nigeria but contrary to that of Aboagye (Aboagye, 2017) for Ghana.

Short-run estimates: In the short run, GDP per capita (lnGDPPC) has a negative and significant impact on carbon emissions. Specifically, a 1% increase in GDP per capita leads to a 2.987% decrease in carbon emissions. This suggests that in the short run, income growth may be associated with improved efficiency in resource use, temporary shifts toward less carbon-intensive activities, or improved access to cleaner technologies and energy-saving practices that reduce emissions. This result is supported by that of Kibria et al. (Kibria et al., 2021) for South Asia and Işık et al. (Işık et al., 2021) for OECD countries. However, it is contrary to that of Ahmad et al. (Ahmad et al., 2021) for Pakistan, Aboagye et al. (Aboagye et al., 2020) and Kwakwa et al. (Kwakwa et al., 2018) for the case of Ghana and Mesagan and Nwachukwu (Mesagan and Nwachukwu, 2018) for Nigeria.

Energy consumption has a positive and significant impact on carbon emissions. The results show that a 1% increase in energy consumption leads to a 0.716% increase in carbon emissions. This suggests that in the short run, increases in energy demand in Kenya are largely met through carbon-intensive energy sources, resulting in higher emissions due to reliance on fossil fuels and limited penetration of cleaner energy alternatives for the manufacturing and industry sectors. As noted by Musibau et al. (Musibau et al., 2021), this result is in line with the assumption that increased energy consumption worsens the environmental quality as a result of its necessity in the production process.

Urbanization has a negative and significant impact on carbon emissions in the short run at the 5% level of significance. That is, a 1% increase in urbanization leads to a 0.101% decrease in carbon emissions, suggesting that in the short run urbanization in Kenya may be associated with improved efficiency in resource use, better access to cleaner energy and infrastructure in urban areas, or a temporary shift away from more carbon-intensive rural economic activities. However, this short-run mitigating effect differs from the long-run dynamics, where urbanization is typically associated with increased emissions due to higher energy demand, transport activity and infrastructure expansion. Similar results are reported by Omoke et al. (Omoke et al., 2020) for Nigeria and Kibria et al. (Kibria et al., 2021). However, they are in contrast to those of Al-mulali et al. (Al-mulali et al., 2015) in Kenya. The negative short-run but positive long-run coefficient for urbanization implies a dynamic and evolving relationship between urban growth and carbon emissions in Kenya.

Trade openness has a negative and significant impact on carbon emissions in the short run. In particular, a 1 percentage point increase in trade openness results in a 1.142% decrease in carbon emissions, suggesting that in the short run, increased integration into international trade in Kenya may facilitate access to cleaner technologies, more efficient production processes and environmentally friendlier imported inputs, thereby reducing emissions. However, this short-run mitigating effect differs from the long-run dynamics, where trade openness is associated with increased emissions due to expansion in production scale and energy-intensive export activities. This result is supported by Özden and Beşe (Özden and Beşe, 2021) in Australia and South Korea, Shahbaz (Shahbaz, 2013) in South Africa, and Ahmed et al. (Ahmed et al., 2019) in Indonesia.

FDI has a positive and significant impact on carbon emissions in the short run. A 1% increase in FDI leads to a 0.123% increase in carbon emissions suggesting that in the short run, FDI inflows in Kenya are associated with increased environmental pressure, likely due to scale effects arising from expanded industrial activity, construction, and energy-intensive production processes. These results are supported by those of Kılıçarslan and Dumrul (Kılıçarslan and Dumrul, 2017) for Turkey and Aboagye (Aboagye, 2019) for South Africa but are contrary to those of Odugbesan and Adebayo (Odugbesan and Adebayo, 2020) for Nigeria.

The differing short-run and long-run impacts of FDI on carbon emissions can be explained using the Pollution Haven and Pollution Halo hypotheses. The short run result is consistent with the Pollution Haven hypothesis, where firms may relocate pollution-intensive activities to countries with relatively weaker environmental enforcement, thereby increasing emissions in the early stages of investment (Zmami and Ben-Salha, 2020). The initial inflows are associated with increased industrial activity, construction, and expansion of energy-intensive production. However, in the long run, where FDI exerts a negative impact on carbon emissions, the result is consistent with the Pollution Halo hypothesis, which posits that multinational firms introduce advanced technologies, improved management practices and higher environmental standards over time. These factors enhance production efficiency and reduce the carbon intensity of economic activity (Aliyu, 2005).

The coefficient of the cointegrating equation as shown by the error correction term (ECT) (-0.811), is negative and statistically significant. A negative and less than one value of the ECT confirms the existence of a stable long-run relationship among the variables as suggested by Pesaran et al. (Pesaran et al., 2001). The magnitude of -0.811 indicates that within a year almost 81% of any short-term disequilibrium or deviation from the long-term equilibrium level of carbon emissions is restored. This means the system has a strong and quick tendency to return to equilibrium after a shock. This result supports the bounds test result, which reported the presence of a long-run relationship among the study variables. The high speed of adjustment indicates that policy or external shocks affecting variables like GDP per capita, energy consumption, trade, FDIs, or urbanization may only cause temporary fluctuations, as the model exhibits strong mean-reverting behavior in the long run (Narayan and Smyth, 2005).

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The 2002 and 2014 dummies representing structural break dates were also significant. The 2002 break has a negative coefficient showing that the break contributed to lower CO₂ emissions. The run-up to 2000 was characterized by economic stagnation, political instability and reduced industrial activity, which likely contributed to lower CO₂ emissions. Also the adoption of renewable energy and shift to cleaner energy sources by the early 2000s contributed to the decline in CO₂ emissions. There was reduced reliance on diesel-powered electricity generation, leading to lower emissions from power plants. The government also prioritized hydropower development to reduce reliance on fossil fuels (ADB, 2022). Thus the government's efforts to transition to cleaner energy sources in the early 2000s played a crucial role in reducing CO₂ emissions.

The positive and significant coefficient for the 2014 CO₂ structural break suggests that CO₂ emissions increased significantly. This trend can be linked to Kenya's economic expansion, industrial growth, infrastructure development and energy policies that led to higher carbon emissions. Also, significant economic and institutional adjustments were witnessed around 2014 as it was preceded by a political transition (2013) and several security threats (2012-2015) that led to more resources being diverted to the security sector. Similarly, the growth of the logistics sector, especially for regional trade within the EAC, led to more diesel truck usage (World Bank, 2023). With limited incentives for green energy in industries, many manufacturers continued to rely on fossil fuels instead of transitioning to cleaner alternatives like electricity and solar power. The diagnostic tests results show the absence of serial correlation and heteroskedasticity. Similarly, Ramsey RESET test results indicate the correct functional form of the model.

Implications and limitations of the study

Overall implication: The study findings emphasize the fact that Kenya's environmental outcomes are shaped by dynamic and time-dependent macroeconomic processes. Achieving sustainable development therefore requires policies that integrate economic growth objectives with environmental sustainability, ensuring alignment with national climate commitments and long-term low-carbon development pathways.

Academic implications: This study contributes to the empirical literature on the carbon emissions-macroeconomic nexus by providing evidence from Kenya using the ARDL approach. The findings highlight the time-varying nature of the relationship between macroeconomic variables and carbon emissions, with both short-run and long-run dynamics. The results further contribute to the EKC debate by showing that GDP per capita reduces emissions in the short run but increases them in the long run, emphasizing the importance of distinguishing between scale, structural, and technology effects in the environmental economics literature.

Managerial implications: The study findings provide important insights for policymakers, energy managers and economic planners. The persistent positive effect of energy consumption on emissions highlights the need for improved energy efficiency and increased adoption of renewable energy technologies. Firms in energy-intensive and industrial sectors should adopt cleaner production methods to reduce their environmental footprint while maintaining productivity and competitiveness.

Research implications: Future research should extend the analysis by incorporating additional variables such as technological innovation, environmental governance, and renewable energy penetration to improve model completeness. The use of nonlinear econometric approaches such as the Nonlinear ARDL model is recommended to capture possible asymmetric relationships. In addition, sectoral and regional-level studies are encouraged to provide more disaggregated insights into emissions dynamics.

Overall limitation: Despite the meaningful insights from this study, there exists a number of drawbacks. Data constraints hindered the addition of factors such as technical innovation and environmental governance measures, which could have enriched the study further. The presence of these limitations, however, provides useful opportunities for future studies to employ non-linear models such as non-linear ARDL or sector-level models to capture deeper insights and dynamic interactions among variables.

Policy limitations: The study does not explicitly model the direct effects of environmental policy instruments such as the Kenya Climate Change Act, the National Climate Change Action Plan or regional frameworks such as the African Continental Free Trade Area. As a result, the influence of policy interventions is only indirectly captured through macroeconomic variables.

Methodological limitations: The study uses annual time series data, which may not capture short-term fluctuations in emissions dynamics. In addition, the ARDL framework assumes linear relationships and does not account for possible nonlinearities or structural asymmetries. The exclusion of robustness checks using alternative econometric techniques also limits the depth of validation of the results.

Conclusions

This study establishes a significant long-run relationship between carbon emissions and selected macroeconomic variables in Kenya using the ARDL approach. The results show that energy consumption consistently increases carbon emissions in both the short and long run, confirming its central role as a key driver of environmental degradation in Kenya. Given the strong and persistent impact of energy

consumption on emissions, Kenya should accelerate its transition toward renewable energy sources, strengthen energy efficiency programs, and reduce reliance on fossil-fuel-based energy systems. These measures are consistent with Kenya's Nationally Determined Contributions (NDCs) under the Paris Agreement.

The findings further reveal heterogeneous and time-dependent effects across variables. GDP per capita reduces emissions in the short run but increases them in the long run, suggesting that initial efficiency gains are eventually outweighed by scale effects associated with sustained economic growth. Given that GDP per capita increases carbon emissions in the long run, Kenya should prioritize policies that promote sustainable and low-carbon economic growth. This includes accelerating structural transformation toward less carbon-intensive sectors such as services and green industries, while encouraging the adoption of clean technologies in production processes. In addition, policies should focus on decoupling economic growth from environmental degradation through investments in energy efficiency, innovation, and environmental regulation, in line with Kenya's NDC commitments and green growth strategy.

Urbanization similarly reduces emissions in the short run but increases them in the long run, reflecting a transition from short-term efficiency improvements to long-term environmental pressures driven by urban expansion and infrastructure demand. It is therefore important for Kenya to integrate urban planning policies that promote sustainable cities through green infrastructure, efficient transport systems, and low-carbon housing development.

Trade openness reduces emissions in the short run but increases them in the long run, indicating that short-term gains from efficiency and technology access are offset over time by expanded production and trade-related energy use. As such, Kenya should integrate environmental considerations into trade policy by promoting green trade standards, supporting environmentally certified exports, and encouraging low-carbon production practices. Where feasible, gradual adoption of carbon pricing mechanisms or carbon border adjustment measures may be considered to align trade expansion with environmental sustainability.

FDI increases emissions in the short run but reduces them in the long run, suggesting a transition from scale-driven effects in early investment phases to long-term gains from technology transfer and improved production efficiency. The mixed effects of foreign direct investment suggest the need for stronger environmental screening of incoming investments. Policy should prioritize FDI into green sectors such as renewable energy, clean manufacturing, and sustainable infrastructure to ensure alignment with Kenya's climate goals. Natural resource rents are statistically insignificant in the short run but exert a negative and significant effect in the long run, indicating that their environmental impact is mainly structural and long-term in nature.

Overall, the results highlight that the relationship between macroeconomic variables and carbon emissions in Kenya is dynamic and time dependent, hence underscoring the importance of distinguishing between short-run adjustments and long-run structural effects in environmental policy design. To achieve sustainable development, Kenya requires integrating macroeconomic policies with environmental objectives by aligning economic growth, trade, investment, and urban development strategies with Kenya's NDC commitments.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Sharon J. Keror, Philip M. Nyangweso, Jared I. Mose

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References

1. Aboagye S: [Economic expansion and environmental sustainability nexus in Ghana](#). African Development Review. 2017, 29:155-168. [10.1111/1467-8268.12247](#)
2. Aboagye S: [Examining the energy consumption and CO2 emissions nexus in South Africa within the Environmental Kuznets Curve hypothesis framework](#). Journal of Economics and Business Research. 2019, 9:64-82.
3. Aboagye S, Appiah-Konadu P, Acheampong V: [Economic expansion and environmental degradation in Ghana: a sector decomposition analysis](#). African Journal of Economic Review. 2020, 8:106-124.
4. Acheampong AO, Opoku EEO: [Environmental degradation and economic growth: Investigating linkages and potential pathways](#). Energy Economics. 2023, 123:[10.1016/j.eneco.2023.106734](#)
5. Ahmad M, Jabeen G, Shah SAA, Rehman A, Ahmad F, İşik C: [Assessing long- and short-run dynamic interplay among balance of trade, aggregate economic output, real exchange rate, and CO2 emissions in Pakistan](#). Environment, Development and Sustainability. 2021, 24:7283-7323. [10.1007/s10668-021-01747-9](#)
6. Ahmed K, Ozturk I, Ghumro IA, Mukesh P: [RETRACTED ARTICLE: Effect of trade on ecological quality: a case of D-8 countries](#). Environmental Science and Pollution Research. 2019, 26:35935-35944. [10.1007/s11356-019-06520-0](#)
7. Al-mulali U, Tang CF, Ozturk I: [Does financial development reduce environmental degradation? Evidence from a panel study of 129 countries](#). Environmental Science and Pollution Research. 2015, 22:14891-14900. [10.1007/s11356-015-4726-x](#)
8. Aliyu MA: [Foreign direct investment and the environment: Pollution haven hypothesis revisited](#). Eighth Annual Conference on Global Economic Analysis. 2005, 2005:36.
9. Ang JB: [CO2 emissions, energy consumption, and output in France](#). Energy Policy. 2007, 35:4772-4778. [10.1016/j.enpol.2007.03.032](#)
10. Antweiler W, Copeland BR, Taylor MS: [Is free trade good for the environment?](#). American Economic Review. 2001, 91:877-908. [10.1257/aer.91.4.877](#)
11. ADB: [Kenya Economic Outlook: Kenya's Economic Growth and Structural Transformations: Regional Integration and Investment Trends](#). AfDB Publications, 2022.
12. Balogh JM, Jámor A: [Determinants of CO2 emission : a global evidence](#). International Journal of Energy Economics and Policy. 2017, 7:217-226.
13. Charfeddine L, Al-Malk A, Korbi K: [Is it possible to improve environmental quality without reducing economic growth: Evidence from the Qatar economy](#). Renewable and Sustainable Energy Reviews. 2018, 82:25-39. [10.1016/j.rser.2017.09.001](#)
14. Chontanawat J: [Relationship between energy consumption, CO2 emission and economic growth in ASEAN: Cointegration and causality model](#). Energy Reports. 2020, 6:660-665. [10.1016/j.egy.2019.09.046](#)
15. Clemente J, Montañés A, Reyes M: [Testing for a unit root in variables with a double change in the mean](#). Economics Letters. 1998, 59:175-182. [10.1016/s0165-1765\(98\)00052-4](#)
16. Cole MA: [Trade, the pollution haven hypothesis and the environmental Kuznets curve: examining the linkages](#). Ecological Economics. 2004, 48:71-81. [10.1016/j.ecolecon.2003.09.007](#)
17. Crippa M, Guizzardi D, Pagani F, et al.: [GHG emissions of all world countries](#). Publications Office of the European Union, Luxembourg; 2024. [10.2760/4002897](#)
18. Dietz T, Rosa EA: [Effects of population and affluence on CO2 emissions](#). Proceedings of the National Academy of Sciences. 1971, 94:175-179.
19. Dinda S: [Environmental Kuznets curve hypothesis: A survey](#). Ecological Economics. 2004, 49:431-455. [10.1016/j.ecolecon.2004.02.011](#)
20. Ehrlich PR, Holdren JP: [Impact of population growth](#). Science, New Series. 1971, 171:1212-1217. [10.1126/science.171.3977.1212](#)
21. Fan Y, Liu LC, Wu G, Wei YM: [Analyzing impact factors of CO2 emissions using the STIRPAT model](#). Environmental Impact Assessment Review. 2006, 26:377-395. [10.1016/j.eiar.2005.11.007](#)
22. Global Carbon Project: [Global carbon budget 2023](#). 2023.
23. Global CCS Institute: [Global status of CCS 2019](#). 2019.
24. Grossman GM, Krueger AB: [Environmental impacts of a North American Free Trade Agreement](#). NBER Working Paper Series, 3914. National Bureau of Economic Research. 1991, [10.3386/w3914](#)
25. Gürlük S: [Economic growth and environment interactions](#). Theories and Effects of Economic Growth. Bertrand RL (ed): Nova Science Publishers, 2011. 171-185.
26. IEA: [World Energy Outlook 2023](#). 2023.
27. IEA: [Global Energy Review: CO2 Emissions in 2021](#). IEA, Paris; 2022.

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28. Işık C, Ongan S, Ozdemir D, Ahmad M, Irfan M, Alvarado R, Ongan A: [The increases and decreases of the environment Kuznets curve \(EKC\) for 8 OECD countries](#). Environmental Science and Pollution Research. 2021, 28:28535-28543. [10.1007/s11356-021-12637-y](#)
29. Kibria MG, Jahan I, Mawa J: [Asymmetric effect of financial development and energy consumption on environmental degradation in South Asia? New evidence from non-linear ARDL analysis](#). SN Business & Economics. 2021, 1:56. [10.1007/s43546-021-00064-7](#)
30. Kılıçarslan Z, Dumrul Y: [Foreign direct investments and CO2 emissions relationship: The case of Turkey](#). Business and Economics Research Journal. 2017, 8:647-660. [10.20409/berj.2017.73](#)
31. KNBS: [Economic Survey 2024](#). Nairobi; 2024.
32. KNBS: [Kenya Economic Survey 2023](#). Government of Kenya, Nairobi; 2023.
33. KNBS: [Kenya Statistical Abstract 2022](#). Kenya National Bureau of Statistics, 2022.
34. Kwakwa PA, Alhassan H, Aboagye S: [Environmental Kuznets curve hypothesis in a financial development and natural resource extraction context: evidence from Tunisia](#). Quantitative Finance and Economics. 2018, 2:981-1000. [10.3934/qfe.2018.4.981](#)
35. Kwakwa PA, Alhassan H, Adu G: [Effect of natural resources extraction on energy consumption and carbon dioxide emission in Ghana](#). International Journal of Energy Sector Management. 2020, 14:20-39. [10.1108/ijesm-09-2018-0003](#)
36. Lotfalipour MR, Falahi MA, Ashena M: [Economic growth, CO2 emissions, and fossil fuels consumption in Iran](#). Energy. 2010, 35:5115-5120. [10.1016/j.energy.2010.08.004](#)
37. Mäler KG: [Economic Growth and the Environment](#). RFF Press, New York; 2013. [10.4324/9781315064123](#)
38. Mesagan EP, Nwachukwu MI: [Determinants of environmental quality in Nigeria: assessing the role of financial development](#). Econometric Research in Finance. 2018, 3:55-78. [10.33119/erfin.2018.3.1.3](#)
39. Mose N, Fumey M, Kipchirchir E: [Drivers of carbon emissions in Kenya: The perspective of technology](#). Asian Journal of Geographical Research. 2024, 7:1-10. [10.9734/ajgr/2024/v7i2226](#)
40. Musibau HO, Shittu WO, Ogunlana FO: [The relationship between environmental degradation, energy use and economic growth in Nigeria: new evidence from non-linear ARDL](#). International Journal of Energy Sector Management. 2021, 15:81-100. [10.1108/ijesm-04-2019-0016](#)
41. Mwatu SM, Yalew AW, Nechifor V, Sahoo A: [Trade policies for low-carbon development in developing countries: Insights from Kenya](#). Development Policy Review. 2026, 44:e70048. [10.1111/dpr.70048](#)
42. Narayan PK: [Are the Australian and New Zealand stock prices nonlinear with a unit root?](#). Applied Economics. 2005, 37:2161-2166. [10.1080/00036840500217887](#)
43. Narayan PK, Smyth R: [Electricity consumption, employment and real income in Australia evidence from multivariate Granger causality tests](#). Energy Policy. 2005, 33:1109-1116. [10.1016/j.enpol.2003.11.010](#)
44. National Environment Management Authority: [Kenya Subsidiary Legislation: Sustainable Waste Management \(Extended Producer Responsibility\) Regulations, 2024](#). Government Printer, Nairobi; 2024.
45. Ng S, Perron P: [Unit root tests in ARMA models with data-dependent methods for the selection of the truncation lag](#). Journal of the American Statistical Association. 1995, 90:268-281. [10.1080/01621459.1995.10476510](#)
46. Odugbesan JA, Adebayo TS: [The symmetrical and asymmetrical effects of foreign direct investment and financial development on carbon emission: evidence from Nigeria](#). SN Applied Sciences. 2020, 2:1982. [10.1007/s42452-020-03817-5](#)
47. Ohnsorge FL, Quaglietti L: [Trade as an Engine of Growth: Sputtering but Fixable \(No. 10356\)](#). World Bank, Washington DC; 2023.
48. Olivier JGJ, Peters JAHW: [Trends in Global CO2 and Total Greenhouse Gas 2019 Report](#). PBL Netherlands Environmental Assessment Agency. 2020,
49. Oluwaseun A: [Analyzing the Impact of Economic Growth, FDI and Energy Use on CO2 Emission in Kenya: An ARDL Approach](#). Research Square. 2025, PREPRINT (Version 1):
50. Omoke PC, Opuala-Charles S, Nwani C: [Symmetric and asymmetric effects of financial development on carbon dioxide emissions in Nigeria: Evidence from linear and nonlinear autoregressive distributed lag analyses](#). Energy Exploration & Exploitation. 2020, 38:2059-2078.
51. OECD: [Environment at a glance 2020](#). OECD Publishing, Paris; 2020. [10.1787/4ea7d35f-en](#)
52. OECD: [Investing in Climate, Investing in Growth](#). OECD Publishing, Paris; 2017. [10.1787/9789264273528-en](#)
53. Özden C, Beşe E: [Environmental Kuznets curve \(EKC\) in Australia: Evidence from nonlinear ARDL model with a structural break](#). Polish Journal of Environmental Studies. 2021, 30:2245-2254. [10.15244/pjoes/127555](#)
54. Panayotou T: [Economic Growth and the Environment \(CID Working Paper No. 56\)](#). Environment and Development. 2001, 114.
55. Parikh J, Shukla V: [Urbanization, energy use and greenhouse effects in economic development](#). Global Environmental Change. 1995, 5:87-103. [10.1016/0959-3780\(95\)00015-g](#)
56. Pesaran MH, Shin Y: [An An autoregressive distributed-lag modelling approach to cointegration analysis](#). Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium. Strøm S (ed): Cambridge University Press, Cambridge; 1998. 31:371-413.

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Analysis of the Effect of Selected Macroeconomic Variables on Carbon Emissions in Kenya

57. Pesaran MH, Shin Y, Smith RJ: [Bounds testing approaches to the analysis of level relationships](#). Journal of Applied Econometrics. 2001, 16:289-326. [10.1002/jae.616](#)
58. Peace J, Ye J: [Market Mechanisms: Options for Climate Policy](#). 2020.
59. Powanga L, Kwakwa P: [Determinants of carbon emissions in Kenya and policy implications](#). Journal of Environmental Management. 2024, 370:122595. [10.1016/j.jenvman.2024.122595](#)
60. Saungweme T, Odhiambo NM: [Inflation and economic growth in Kenya: An empirical examination](#). Advances in Decision Sciences. 2021, 25:1-25. [10.47654/v25y2021i3p1-25](#)
61. Shahbaz M: [Does financial instability increase environmental degradation? Fresh evidence from Pakistan](#). Economic Modelling. 2013, 33:537-544. [10.1016/j.econmod.2013.04.035](#)
62. Shahbaz M, Zakaria M, Shahzad SJH, Mahalik MK: [The energy consumption and economic growth nexus in top ten energy-consuming countries: Fresh evidence from using the quantile-on-quantile approach](#). Energy Economics. 2018, 71:282-301. [10.1016/j.eneco.2018.02.023](#)
63. Sharma SS: [Determinants of carbon dioxide emissions: Empirical evidence from 69 countries](#). Applied Energy. 2011, 88:376-382. [10.1016/j.apenergy.2010.07.022](#)
64. Sibanda K, Garidzirai R, Mushonga F, Gonesse D: [Natural resource rents, institutional quality, and environmental degradation in resource-rich sub-Saharan African Countries](#). Sustainability. 2023, 15:1141.
65. Stern DI: [The rise and fall of the Environmental Kuznets Curve](#). World Development. 2004, 32:1419-1439. [10.1016/j.worlddev.2004.03.004](#)
66. Tufail M, Song L, Adebayo TS, Kirikkaleli D, Khan S: [Do fiscal decentralization and natural resources rent curb carbon emissions? Evidence from developed countries](#). Environmental Science and Pollution Research. 2021, 28:49179-49190. [10.1007/s11356-021-13865-y](#)
67. [The Global Economy](#). (2024). Accessed: April 2026: <https://www.theglobaleconomy.com/>.
68. United Nations: [Transforming our world: The 2030 agenda for sustainable development](#). 2015.
69. United Nations Economic Commission for Africa (UNECA): [Kenya's Green Supplement focusing on tea and coffee value chains](#). Addis Ababa. 2024,
70. UNCTAD: [World Investment Report 2023: Investing in Sustainable Energy for all](#). United Nations, Geneva; 2023.
71. UNECA: [Economic Report on Africa 2021: Addressing poverty and vulnerability in Africa during the COVID-19 pandemic](#). United Nations Economic Commission for Africa, 2021.
72. UNFCCC: [Nationally determined contributions under the Paris Agreement: Synthesis report by the secretariat](#). 2021.
73. UNEP: [Emissions gap report 2024: No more hot air ... please! With a massive gap between rhetoric and reality, countries draft new climate commitments](#). UNEP, Nairobi; 2024. [10.59117/20.500.11822/46404](#)
74. UNFCCC: [Yearbook of global climate action 2020](#). UNFCCC, 2020.
75. World Bank: [World Bank Open Data](#). World Bank, Washington DC; 2023.
76. World Bank: [World Development Indicators](#). Washington, DC. 2022,
77. World Bank: [Kenya Economic Update, November 2020: Navigating the Pandemic](#). 2020. [10.1596/34819](#)
78. Wooldridge JM: [Introductory econometrics: A modern approach \(6th ed.\)](#). Cengage Learning, Boston, MA; 2016.
79. Zmami M, Ben-Salha O: [An empirical analysis of the determinants of CO2 emissions in GCC countries](#). International Journal of Sustainable Development & World Ecology. 2020, 27:469-480. [10.1080/13504509.2020.1715508](#)
80. Zuo S, Zhu M, Xu Z, Oláh J, Lakner Z: [The dynamic impact of natural resource rents, financial development, and technological innovations on environmental quality: Empirical evidence from BRI economies](#). International Journal of Environmental Research and Public Health. 2021, 19:130. [10.3390/ijerph19010130](#)

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