World Development Sustainability 4 (2024) 100134

Contents lists available at ScienceDirect

World Development Sustainability

journal homepage: www.elsevier.com/locate/wds

The impact of trade on environmental quality and sustainable development in Ghana

Malik Dawuda Kindo [a,b,*], Aziz Abdulai Adams [c], Jamal Mohammed [b,d]

[a] Department of Economics, University of Ghana, Legon, Accra, Ghana
[b] African Development Resource Research Institute, Ghana
[c] United Graduate School of Agricultural Science, Tokyo University of Agriculture and Technology, Japan
[d] Department of General Studies, Koforidua Technical University, Ghana

ARTICLE INFO

JEL Classification:
F14
F18
F64
Q01
Q56

Keywords:
Sustainable Development
Environmental quality
Trade
Distributed lag model
Ghana

ABSTRACT

Since gaining independence in 1957, Ghana has significantly increased its economic ties with the global community through trade liberalization policies. However, this integration has profoundly affected the environment, particularly in utilizing natural resources, and has subsequently impacted sustainable development. This study examines the relationship between trade, environmental considerations, and sustainable development within the Ghanaian context. Using the autoregressive distributed lag (ARDL) error correction estimation technique, we found that trade positively impacts sustainable development in Ghana despite causing adverse environmental effects. This suggests that economic gains are prioritized over environmental preservation, indicating weak sustainability. However, sustainable development requires a balance between economic, social, and environmental factors, and a shift towards strong sustainability may be necessary for long-term sustainability. Therefore, pivotal policy interventions are warranted to navigate the path toward strong sustainability. Mechanisms that ensure the judicious pricing of Ghana's forest and natural resources are necessary to optimize resource exploitation while mitigating negative externalities. Ghana can promote inclusive and sustainable development by establishing a delicate balance between economic expansion and environmental stewardship.

1. Introduction

Situated at the heart of West Africa, Ghana has become a key player in global trade, wielding substantial influence through its strategic exports of gold, cocoa, and oil. As of 2020, Ghana is the largest gold producer in Africa, contributing 90,000 kilograms to the global gold supply, reinforcing its position as a critical player in the bullion market [1]. This impressive volume exemplifies the country's indispensable role in stabilizing global markets and meeting the insatiable demand for this precious metal. In the 2020/2021 season, Ghana's cocoa sector produced 1.1 million metric tons of cocoa beans, making it the second-largest producer worldwide [2]. This high output has helped meet the world's demand for chocolate and cocoa products, cementing Ghana's significance in the confectionery industry. Ghana's oil industry is also growing, with over 173,000 barrels of crude oil produced daily in 2020 [3]. The Ministry of Energy of Ghana anticipates production to reach 500,000 barrels per day by 2024 [3]. Ghana exports 56% of its oil production [4]. In 2022, the nation's total exports were worth US$16.3 billion [2]. This robust trade volume, driven mainly by gold, cocoa, and oil, underscores Ghana's role in shaping the economic discourse on a worldwide scale.

However, Ghana's economic growth has come at a significant environmental cost. The production and export of these commodities have led to severe environmental challenges, imperiling the nation's pursuit of sustainable development. Gold mining, in particular, has a significant environmental toll. Using toxic chemicals like cyanide and mercury in mining operations has led to extensive environmental degradation, with pollutants seeping into water bodies, soil, and the atmosphere. This endangers human health and affects the overall ecological balance. About 60% of Ghana's water sources are now polluted, primarily due to illegal mining activities, which affect human health and undermine the agricultural sector. Deforestation is also a significant issue, with Ghana's forest cover plummeting by 80%, from an estimated 8.2 million to 1.6 million hectares [5]. This has compromised the habitats of countless plant and animal species, disrupting ecosystems and affecting the overall ecological balance. Climate change also poses a severe threat to

* Corresponding author.
E-mail address: dkmalik@st.ug.edu.gh (M.D. Kindo).

https://doi.org/10.1016/j.wds.2024.100134
Received 28 October 2023; Received in revised form 24 February 2024; Accepted 5 March 2024
Available online 6 March 2024

Ghana, with rising temperatures and sea levels putting nearly half of Ghana's coastline at risk of erosion and flooding. Annual flooding affects around 45,000 Ghanaians, and agriculture, employing over half of the population, is vulnerable to climate-induced disruptions. In pursuit of economic growth, Ghana's over-reliance on exporting environmentally-intensive commodities has led to significant environmental devastation, from contaminated water bodies and deforested lands to polluted air and climate change. Achieving a balance between economic prosperity and environmental sustainability is crucial for Ghana's future.

The literature on the effects of trade on sustainable development and environmental degradation in Ghana and Africa is limited despite the severity of the situation. The existing studies, particularly those conducted in Ghana [6–11], mainly focus on the connection between trade and economic growth. They examine how trade openness affects economic growth but overlook broader aspects of sustainable development and environmental sustainability. For instance, Enu et al. [11] studied how foreign trade impacted Ghana's economic growth between 1980 and 2012. Their findings indicate relationships between variables such as real gross domestic product, exports, imports, and foreign direct investment (FDI). Exports positively influenced real gross domestic product, while imports and FDI had adverse effects [11]. Although these contributions provide valuable insights into the economic implications of trade in Ghana, it is essential to recognize that there remains a significant gap in assessing its impact on environmental sustainability and sustainable development as a whole. Addressing this research gap is crucial, considering Ghana's growing environmental challenges associated with commodity production and exportation. Enu et al.'s [11] work emphasizes the need to consider the broader implication of trade on economic growth, highlighting the importance of assessing sustainability within this context, thereby providing a foundation for comprehensively evaluating the impact of trade on sustainable development.

In the broader African context, research has primarily focused on environmental measures, specifically carbon dioxide (CO_2) emissions, as a key measure of sustainable development [12–16]. Although these studies have significantly contributed to our understanding of the environmental impact of trade, their emphasis on CO_2 emissions inadvertently overlooks the broader economic and social aspects of sustainability. For example, Asongu and Odhiambo [12] examined how increased openness affects CO_2 emissions in Sub-Saharan Africa. Their findings revealed that enhancing trade openness positively influences CO_2 emissions, while increased FDI has a negative impact. The relationship between CO_2 emissions and trade follows a Kuznets shape, while the connection between CO_2 emissions and FDI inflows is a U-shape [12]. Recognizing the non-linear nature of these relationships emphasizes the need to consider the environmental consequences of trade when pursuing sustainable development objectives. However, solely focusing on CO_2 emissions overlooks the overall impact of sustainable development.

To bridge this research gap, the current study adopts a more integrated approach by utilizing a composite sustainable development index for comprehensive evaluation. This approach considers environmental, economic, and social factors, enabling us to understand the complex dynamics. Such an inclusive methodology aligns with sustainable development imperatives and establishes a solid basis for crafting effective policy frameworks encompassing Ghana and other resource-rich African economies. Ultimately, this research aims to provide timely and relevant insights that support global efforts towards building a sustainable future. By contributing significantly to discussions surrounding sustainable development in natural resource-abundant nations, we can work towards creating a better world.

This study investigates the connection between trade, environmental quality, and sustainable development in Ghana. Addressing the research gap, the study found that trade positively impacts sustainable development whilst adversely impacting the environment in Ghana. This suggests that the country prioritizes economic gains over environmental preservation, aligning with weak sustainability. The remainder of the study is structured as follows. Section 2 explains the methodology, focusing on the theoretical framework, model estimation, empirical strategy, and data description. Section 3 presents the results and discussion, including descriptive statistics of the key variables of interest, stationarity, and co-integration results for the selection of the ideal time series model, short-run and long-run autoregressive distributed lag (ARDL) results of trade on the environment, and sustainable development, and discusses the implications of the results to policymakers. Finally, we report the diagnostics tests, indicating the robustness of the regression models used in the analysis. Section 4 concludes and makes recommendations for Ghana's strong sustainable development, encompassing the economic, environmental, and social dimensions of sustainability.

2. Methodology

2.1. Theoretical framework and model estimation

Fig. 1 illustrates the framework linking trade, environmental quality, and sustainable development. International trade plays a pivotal role in driving economic growth and development. When countries participate in open trade, there are numerous benefits. Consumers can access diverse goods and services, businesses can take advantage of innovative technologies from various parts of the world, producers can expand their reach to bigger markets, and resources can be utilized more efficiently. The comparative advantage theory of trade [17] predicts substantial gains from trade liberalization, emphasizing the benefits of specialization based on comparative advantage. However, it is crucial to recognize that trade liberalization can have significant environmental implications, particularly in developing countries. One key concern arises from potentially lax environmental regulations in these regions. This may lead to practices that can be harmful to the environment. Concerns have been raised about various environmental issues, such as air and water pollution, the depletion of natural habitats, the extinction of species, and the improper disposal of electronic and plastic waste. Among these, global pollutants, with a particular emphasis on carbon dioxide emissions, stand out as critical focal points; a crucial concept in this context is the *pollution haven hypothesis* [18]. This hypothesis suggests that countries with less stringent environmental regulations may attract more pollution-intensive industries. They may do so to cut production costs. This can lead to a concentration of pollution-intensive activities in these regions. As a result, some argue that trade liberalization, particularly in the absence of strong environmental safeguards, could lead to higher environmental degradation.

As per Antweiler et al. [18], the impacts of trade liberalization on the environment are ultimately shaped by three key factors: scale, technique, and composition effects. The scale effect pertains to the influence of an increase in production, such as economic growth, on the environment. In contrast, the technique effect concerns how an increase in income affects the environment. This relates to the effect of implementing more stringent environmental regulations, which become feasible as additional income elevates the demand for an improved environmental state. The composition effect elucidates how the output structure influences the environment, determined by the degree of trade openness and the comparative advantage of a given country [19]. This effect may yield positive or negative outcomes, contingent upon a country's resource abundance and the efficacy of its environmental policies. Trade openness can augment production, enhance income levels, and reshape output.

Consequently, it can impact the environment through scale, technique, and composition effects. The current study formulates a framework for assessing trade openness's sustainability and environmental impact, building on the abovementioned discussion. The research employs a streamlined adaptation of Antweiler et al.'s [18] methodology to dissect the environmental consequences of trade. Within this model, we

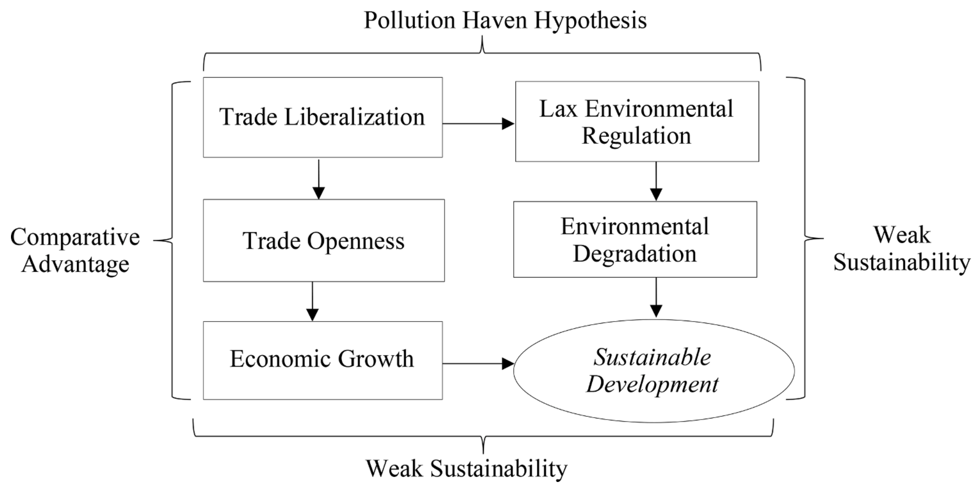

Fig. 1. Effect of trade openness on environmental quality and sustainable development

examine a small open economy that produces two ultimate goods, denoted as X and Y. The process relies on the utilization of natural capital (N) and human capital (H) as its core components (K). Industry Y substantially emphasizes human capital utilization and operates without generating pollution. Conversely, industry X heavily relies on natural resources and is associated with pollution emissions.

Under the assumption of constant returns to scale, we can define unit cost functions $C_X(w,r)$ and $C_Y(w,r)$ to delineate the production technologies for commodities X and Y, respectively. In this context, 'w' signifies the wage rate, representing the remuneration for human capital, while 'r' denotes rent, symbolizing the compensation for natural capital.

We define a straightforward emission function that establishes a connection between economic activity and environmental degradation as follows:

$$\mathrm{E} = \mathrm{zX} = \mathrm{z}\varnothing\mathrm{S} \tag{1}$$

Here, $\varnothing$ represents the proportion of X (the pollution-intensive good) in the overall output. This Equation offers a straightforward breakdown: environmental degradation (E) depends on the pollution intensity of the dirty industry (denoted as 'z'), the significance of the industry in the overall economic landscape ($\varnothing$), and the comprehensive scale of the economy (represented by 'S').

In the specific context of Ghana, the proposed framework provides a valuable tool for comprehensively assessing the sustainability and environmental implications of trade openness. The framework acknowledges the interplay between natural and human capital utilization in production, particularly in two key industries, X and Y, which play pivotal roles in the economy. Ghana's trade patterns have significant implications for environmental sustainability. The country is known for exporting essential commodities with distinct environmental footprints, notably gold, cocoa, and oil. Gold mining is a crucial sector of the country's economy. However, it is also associated with environmental challenges. The extraction of gold often involves processes like heap leaching or cyanide treatment, which can lead to the release of toxic chemicals into the environment. Improper waste disposal and deforestation, often associated with mining activities, further contribute to environmental degradation. If Ghana's trade pattern leans heavily towards gold exports, it implies a significant reliance on Industry X, which is resource-intensive and pollution-heavy. This could lead to substantial environmental degradation, particularly in areas where gold mining operations are concentrated. Cocoa is another vital export commodity for Ghana. While cocoa production may not involve significant pollution, it has indirect environmental implications. The expansion of cocoa farms often leads to deforestation, as farmers clear land for cultivation. This can disrupt local ecosystems, reduce biodiversity, and contribute to climate change. While cocoa production is not as directly polluting as some other industries, it highlights the importance of considering the broader environmental impact of trade patterns. If cocoa exports dominate Ghana's trade profile, it underscores the significance of sustainable land management practices to mitigate environmental harm. Furthermore, as Ghana continues to develop its oil industry, it is paramount to recognize the potential environmental impacts associated with oil extraction and production. This sector can have significant environmental consequences, including oil spills and habitat disruption, if not managed judiciously.

In summation, the impact of trade on the environment and sustainable development in Ghana pivots on the pollution intensity of critical industries, including gold, oil, and cocoa. Moreover, it is contingent on the relative economic significance of these industries within the broader framework of the nation's economy. Achieving a harmonious balance between economic prosperity and environmental preservation is critical for Ghana's enduring pursuit of sustainable development.

The objective is to compute Eq. (2) for Ghana at time t, operating under the assumption that environmental degradation is contingent on trade openness, with other environmental quality factors exerting a linear influence on the environment.

$$\mathrm{E_t} = B_i E_t \text{ For } \mathrm{t} = 1, 2, \cdots, \mathrm{T} \tag{2}$$

Where E_t represents environmental degradation; X is a vector of independent variables; B_i is a vector of parameters that measure the impact of the independent variables on the environment. The overall form of the model to ascertain the impact of trade on the environment following the estimation of Saboori et al. [20] is expressed as follows:

$$\mathrm{E_t} = \mathrm{F}(\mathrm{Y_t}, \mathrm{Z_t}) \tag{3}$$

Where Y is income (real GDP per capita), and Z is a vector of control variables that may contribute to environmental degradation.

The vector of control variables in this study includes trade openness (TRADE), energy consumption (ENERGY), FDI, and Urbanization (URBAN) following the estimation of Saboori et al. [20]. Thus,

$$\mathrm{Z_t} = \mathrm{F}(\mathrm{TRADE_t}, \mathrm{ENERGY_t}, \mathrm{FDI_t}, \mathrm{URBAN_t}) \tag{4}$$

Replacing the vector Z with its elements in Eq. (3) yields the function in Eq. (5). Therefore, the model for examining trade's impact on Ghana's environmental quality is shown in Eq. (5) (Model 1).

$$\mathrm{E_t} = \mathrm{F}(\mathrm{Y_t}, \mathrm{TRADE_t}, \mathrm{ENERGY_t}, \mathrm{FDI_t}, \mathrm{URBAN_t}) \tag{5}$$

We employ a sustainable development model (henceforth SD model) to scrutinize the influence of trade on sustainable development in

Ghana, encompassing economic, environmental, and social facets. Rooted in the propositions of the green theory advocated by Cherp et al. [21], Wenden [22], and Antweiler et al. [18], as well as incorporating the *pollution haven hypothesis* and Antweiler decomposition, the model addresses the following dimensions:

Economic Impacts (Y): Changes in per capita incomes, net capital formation, and employment (proxied by real GDP per capita).

Environmental Impacts (NRR): Changes in air, water, and land quality, biological abundance and diversity, and other environmental resource stocks (proxied by Natural Resource Rent).

Social Impacts (EDU): The human capital impact, including effects on levels of health and education (proxied by education)

The SD model (Model 2) following the estimation of Antweiler et al. [18], Twerefou et al. [23], and Jalil and Feridun [24] is specified in Eq. (6) as follows:

$$SD_t = F(Y_t, TRADE_t, EDU_t, NRR_t, ENERGY_t, FDI_t) \tag{6}$$

2.2. Empirical estimation strategy

Fig. 2 shows the steps in model selection for the analysis of the study, from variables selection to the ARDL model. The empirical evaluation of the relationship between trade and sustainable development in Ghana employs the ARDL model. This robust methodology enables a comprehensive analysis of both short-term and long-term dynamics among the variables of interest. The analytical framework begins with a unit root test and the ARDL bound co-integration test and finally estimates the short- and long-run models to address research questions. This structured approach ensures a thorough investigation into the intricate interplay between trade activities, environmental degradation, and sustainable development outcomes in the Ghanaian context.

2.2.1. Unit root test

A rigorous unit root test was systematically conducted on the variables under scrutiny to ascertain the stationary conditions with the potential non-stationarity inherent in macroeconomic time series data. The unit root test serves a dual purpose. First, it discerns whether the variables possess attributes like mean reversion and finite variance. Second, it aids in determining whether the variables are characterized by stationarity or non-stationarity and further identifies their specific order of integration. Comprehending the order of integration holds significance as it facilitates assessing long-term relationships among the variables. The study employs a stationarity test based on the Augmented Dickey-Fuller (ADF) test, with results corroborated with the Phillips-Perron (PP) test. The ADF test for unit root entails the estimation of an equation of the form:

$$\Delta y_t = \varnothing_0 + \partial y_{t-1} + \sum_{j=1}^{p} \partial_j \Delta y_{t-1} + e_t \tag{7}$$

Where $\mathbf{y_t}$ denotes a vector representing the time series variables involved in a distinct regression analysis, which, in the context of this study, encompasses the variables under investigation; t stands for the time trend, illustrating the progression of time in the dataset; Δ denotes the first difference operator, which is employed to compute the changes in the values of the variables over time; $\mathbf{e_t}$ represents the error term, encapsulating the discrepancy between the observed values and the values predicted by the regression model; P signifies the optimal lag length, which is a crucial parameter in time series analysis, helping to determine the number of lagged values considered in the analysis.

The ADF test for unit root operates under the premise of testing the null hypothesis that a unit root is present in the examined variable against the alternative hypothesis that the variable is stationary. Consequently, not rejecting the null hypothesis implies that the series possesses a unit root and is non-stationary. Conversely, rejecting the null hypothesis of a unit root suggests that the series is stationary, indicating a stable behavior over time.

2.2.2. Co-integration

The study proceeded with the ARDL bound testing technique, which provides distinctive advantages and overcomes the limitations associated with traditional co-integration methods. Engle and Granger's [26] residual-based procedure and Johansen's [27] system-based reduced rank regression technique are widely used for co-integration analysis. However, they share a common constraint as all the time series variables must be integrated of order one (I(1)). This introduces uncertainty and often necessitates pretesting when evaluating long-term relationships, a concern underscored by Pesaran, Shin, and Smith [28].

In contrast, the ARDL bound testing technique offers several key benefits. Firstly, it eliminates the need for testing the order of integration, enabling its application even when variables exhibit different orders of integration [29], such as I(0) or I(1). This flexibility is particularly advantageous for accommodating various data types in the analysis. Moreover, the ARDL approach, as demonstrated by Banerjee

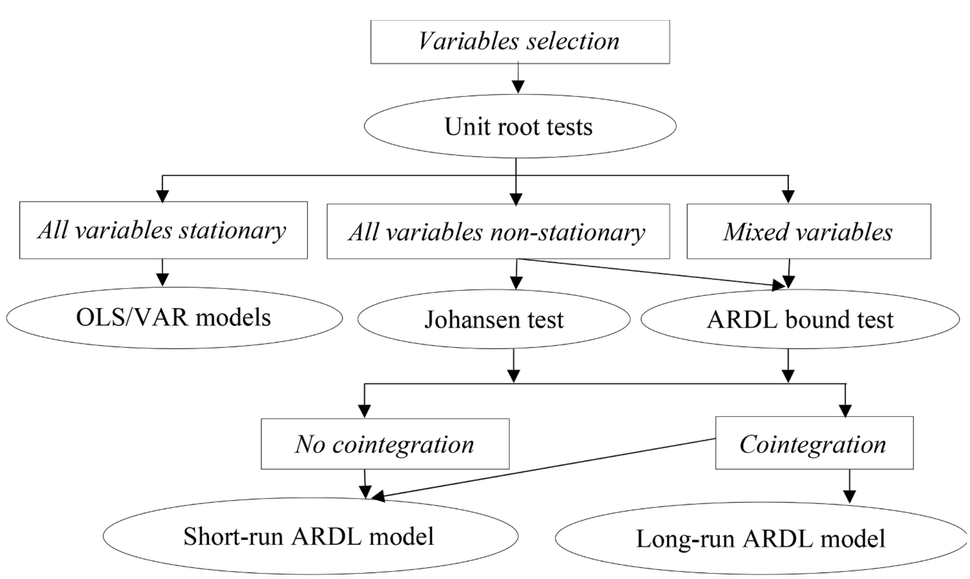

Fig. 2. Method selection for time series data. OLS: Ordinary least squares; VAR: Vector autoregressive
Source: Adapted from Shrestha and Bhatta [25]

et al. [30], is particularly suitable for small sample data, rendering it more applicable to our data, which consists of a relatively limited period from 1970 to 2021. Additionally, the ARDL method employs a single equation framework, simplifying interpretation compared to techniques involving multiple equation setups, like VAR models. This characteristic enhances the clarity and transparency of the analytical process.

Furthermore, the ARDL bound testing approach provides unbiased and efficient estimates, effectively addressing issues related to serial correlation and endogeneity [31]. The bounds testing procedure comprises three distinct steps. Initially, an F-test is employed to ascertain the presence of a co-integration relationship. Notably, Pesaran [29] furnishes critical values contingent on two distinct assumptions. The upper critical bound presupposes all variables to be integrated of order one (I (1)), while the lower critical bound assumes all variables to be integrated of order zero (I(0)). Should the computed F-statistic surpass the upper critical value, the null hypothesis is rejected, signifying the existence of co-integration among the variables, irrespective of whether they are I(1) or I(0). Conversely, if the F-statistic falls below the lower critical value, the null hypothesis of no co-integration cannot be rejected. The result remains inconclusive when the F-statistic falls within the bounds (i.e., between the lower and upper critical values).

We estimate the ARDL long-run model in Eq. (8) after establishing the presence of co-integration as specified:

$$\mathrm{Y_t} = \beta_0 + \sum_{i=1}^{p} \beta_{1i}\mathrm{Y}_{t-1} + \sum_{i=0}^{p} \beta_{2i}\mathrm{X}_{t-i} + \sum_{i=0}^{p} \beta_{3i}\mathrm{CV}_{t-i} + \varepsilon_t \tag{8}$$

The study derived the short-run dynamic parameters in the third step by estimating an error correction model linked to the long-run estimates. This model elucidates the speed at which the system adjusts to restore equilibrium, as indicated by the adjustment term. The model is specified as follows:

$$\mathrm{Y_t} = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i}\Delta\mathrm{X}_{t-i} + \sum_{i=1}^{n} \alpha_{2i}\Delta\mathrm{CV}_{t-i} + \theta\mathrm{ECT}_{t-1} + \mathrm{e_t} \tag{9}$$

Where Y represents the dependent variables within the specified model, X represents the independent variables, CV denotes the control variables, and Δ signifies the first difference operator. Lag order selection, guided by the Akaike Information Criterion (AIC), is represented by P and n. The drift parameters are represented by β_0 and α_0. The error terms, ε_t and $\mathbf{e_t}$, adhere to a normal distribution with variance δ^2. The coefficient θ indicates the pace at which the long-term equilibrium reverts to normalcy following a shock. Concurrently, the error correction term (ECT_{t-1}) captures the residual from the co-integration equation lagged by one period. The lagged error correction term's anticipated negative and statistically significant coefficient further substantiates a co-integrating relationship among the variables.

Using the ARDL and its associated error correction model, this study will meticulously examine trade's long-term and short-term impact on the environment and Ghana's sustainable development. This analysis considers dynamic shifts and adjustments in the relationship over time. This rigorous approach offers a comprehensive understanding of the intricate interplay between trade and sustainable development, ensuring robust and credible findings for scholarly dissemination.

2.3. Data

The study harnessed a rich dataset comprising annual time series data from 1970 to 2021. Each variable within the dataset comprises 52 observations, except for FDI, which recorded 51 observations due to one missing value. This temporal framework is significant for Ghana as it encapsulates pivotal phases, including the Economic Recovery Program (ERP), the Structural Adjustment Program (SAP), and the sweeping waves of economic and trade liberalizations. These chronological landmarks are crucial since they reflect transformative policy shifts that shaped Ghana's economic trajectory. The data availability for the chosen variables also guided the selection of this timeframe. The data were obtained from the World Development Indicators (WDI) and International Monetary Fund (IMF) Databases. The key variables of interest encompass a spectrum of critical dimensions: Sustainable development (Adjusted Net Savings), CO2 emissions (kg per 2017 PPP $ of GDP), real GDP per person (GDP), energy consumption (ENERGY), trade openness (TRADE), education (EDU), foreign direct investment (FDI), and natural resource rent (NRR). These variables offer a panoramic view of Ghana's economic, trade, and sustainable development landscape, collectively shaping the narrative of this study.

Table 1 presents a description of the variables. The study measures sustainable development following the WDI as the Adjusted Net Savings

Table 1
Description of variables used in models.

Variable	Description	Justification
Dependent variables		
CO2	*CO2 per capita:* Carbon dioxide (CO2) emissions per capita as a proxy for environmental quality. Measured as kilograms per 2017 PPP US$ of GDP.	Song and Zhou [32]; Akbostanci et al. [33]; Sharma [34]; Wang [35]
ANS	*Adjusted Net Savings:* The rate of gross national savings after taking into account the depletion of fixed capital, education expenditure, depletion of certain natural resources (energy, minerals, and net forest depletion), and pollution damages of CO2 and SPM [36] as a measure of sustainable development. Measured as a percentage of gross national income.	Twerefou et al. [23]
Independent variables		
TRADE	*Trade openness:* The sum of total exports and imports of goods and services expressed as a percentage of GDP.	Sharma [34]; Baek et al. [37]; Jayanthakumaran and Liu [38]; Kirkpatrick et al. [39]
Controls		
GDP	*Real GDP per capita:* Real GDP per capita measures real income in constant 2000 US Dollars as an indicator of economic growth.	Iwata et al. [40]; He et al. [41]; Franklin and Ruth [42]; Sharma [34]
ENERGY	*Energy Consumption:* The amount of energy use measured in kilograms of oil equivalent per capita.	He et al. [41]; Wang [35]; Jayanthakumaran et al. [43]
EDU	*Education:* A proxy for measuring human capital, using current education expenditure, measured as percentage of total expenditure in public institutions.	Wenden [22]
FDI	*Foreign Direct Investment:* The sum of equity capital, reinvestment of earnings, and other long-term and short-term capital, as shown in the balance of payments, as a percentage of GDP. Measures the inward and outward flows and stock.	Baek and Koo [44]; Jalil and Feridun [24]; Xing and Kolstad [45]
NRR	*Natural Resource Rent:* The sum of the rents for oil, natural gas, coal (hard and soft), minerals, and forests expressed as a percentage of GDP.	Kirkpatrick et al. [39]; Wenden [22]
URBAN	*Urbanization:* The annual urban population growth rate in percentages.	Iwata et al. [40]; Sharma [34]; Hossain [46]

Source: Authors' Compilation
SPM: Suspended Particulate Matter

(ANS). ANS represents a nation's aggregate savings, including financial savings, investments in human capital, environmental asset preservation, and other forms of capital. This metric offers a comprehensive view of a country's savings behavior, accounting for traditional savings, investments in human development, and the preservation of natural resources. Environmental quality is measured using CO2 emissions per unit of economic output, adjusted for purchasing power parity (PPP) in 2017. It indicates a country's efficiency in resource utilization for economic output. Lower emissions per unit of GDP imply a more environmentally efficient economy. By employing this comprehensive framework, our study advances sustainable development assessment methodologies. Incorporating ANS, the WDI's approach, and environmental quality metrics enhances the depth and breadth of our analysis, ensuring an impactful contribution to the scholarly discourse on sustainable development. This study measured trade openness as an economic indicator that reflects the openness of an economy to international trade to its overall economic output, represented by its GDP. This indicator is crucial for understanding the level of economic integration with the global market and the extent to which a nation relies on international trade for economic growth and development.

3. Results and discussion

3.1. Descriptive statistics and overview of trade in Ghana

Table 2 presents summary statistics of the variables of interest spanning 52 annual series. The ANS, a proxy for sustainable development, accounts for the multifaceted dimensions of sustainability, encapsulating the depletion of natural resources and the incursion of pollution damages.

The ANS spans a wide range in Ghana, from a deficit of -5.38 to a notable surplus of 13.79. This indicates a dynamic economic situation. When ANS is negative, as seen in some cases, it raises concerns about how the country's resources are managed. For instance, when ANS reaches -5.38, it suggests that the country might be using up more capital than it is investing; thus, natural resources and capital stock may be diminishing faster than replenishing. This emphasizes the importance of careful resource management and sustainable economic practices for Ghana's future development. Ghana's significant depletion of forests is one of the most pressing instances of natural resource over-exploitation. This issue carries immense weight, as forests are critical pillars in maintaining ecological equilibrium, bolstering biodiversity, and providing essential ecosystem services. In the context of Ghana, this concern reaches a paramount level of urgency due to the multifaceted pressures faced by its forest cover. Various activities contribute to the heightened pressure on Ghana's forests. Notably, illegal logging operations, often driven by demand for valuable timber, represent a substantial threat.

Additionally, large-scale commercial logging endeavors further exacerbate the situation. The expansion of agricultural activities and the surge in artisanal mining, particularly in gold-rich areas, have led to substantial clearances of forested lands. Though economically driven, these practices inflict severe ecological repercussions—the issue of natural and human-induced wildfires further compounds the problem. The deliberate setting of fires to clear land for agricultural purposes can quickly spiral out of control, resulting in extensive damage to forested areas. This phenomenon adds to the cumulative stress experienced by Ghana's forests. As urbanization surges and population growth continues, human settlements and infrastructure projects have progressively encroached upon forested lands. The rising demand for housing and industrial zones drives this encroachment. The Atewa Range Forest Reserve in the Eastern Region of Ghana starkly illustrates this phenomenon. This once-thriving forest ecosystem, celebrated for its rich biodiversity and distinctive flora and fauna, has suffered notable degradation from illegal logging, small-scale mining, and agricultural encroachment. The seriousness of the situation is emphasized by a striking statistic: Ghana's forest cover has plummeted from an estimated 8.2 million hectares in times past to a mere 1.6 million hectares today. This alarming figure signifies an astounding 80% depletion rate [47]. This drastic reduction highlights the severity of the issue, painting a vivid picture of the rapid decline in Ghana's once-abundant forested areas. The repercussions of this over-exploitation are extensive. It translates into habitat loss and directly threatens the survival of countless plant and animal species intricately linked to these forests.

Furthermore, the role of forests in regulating climate patterns must be balanced, and their depletion can exacerbate the effects of climate change. Local communities are also profoundly affected, as they rely on forest resources for their livelihoods, including non-timber forest products like fruits, nuts, and medicinal plants. Moreover, forests serve as natural water catchments, and their destruction can disrupt local water cycles, leading to soil erosion and reduced water quality. Addressing this formidable challenge requires a comprehensive approach. It necessitates the implementation of sustainable forest management practices, stringent conservation efforts, and the rigorous enforcement of anti-deforestation laws. This concerted endeavor is imperative to safeguarding Ghana's remaining forests, preserving biodiversity, and securing the well-being of both present and future generations.

Ghana's average trade, measured as a percentage of GDP from 1970 to 2021, is 56.44, with a median of 57.93, signifying a considerable proportion and resilience of trade relative to GDP. This suggests that the value of goods and services traded internationally is a significant driver of Ghana's economic activity. Ghana's favorable trading environment and robust regulatory framework are the reasons behind this achievement. The Ghana International Trade Commission (GITC), established through an Act of Parliament in 2016, regulates the nation's international trade activities following global guidelines, particularly those set forth by the World Trade Organization (WTO). Before the GITC, the Tariff Advisory Board, an administrative body under the Ministry of Trade and Industry, provided policy advice on tariff adjustments and safeguard measures. The transition to GITC marked a significant shift in Ghana's trade regulatory framework, signifying the country's commitment to a well-regulated international trade environment that aligns with global standards. This dedicated institution plays a crucial role in ensuring fair competition, adherence to international trade rules, and protection of domestic industries, thus contributing to Ghana's balanced and regulated international trade landscape

Table 2
Descriptive statistics of key variables.

	ANS	C02	TRADE	FDI	ENERGY	GDP	NRR	EDU
Mean	3.73	0.11	56.44	824.01	20.04	3175.31	8.99	18.76
Median	2.26	0.11	57.93	89.30	19.50	2774.33	8.84	19.50
Minimum	-5.38	0.07	6.32	-18.26	1.00	2005.74	2.34	1.00
Maximum	13.79	0.13	116.05	3879.00	45.00	5516.72	16.29	38.00
Std. Dev.	6.02	0.02	27.66	1315.31	14.36	997.77	3.52	10.19
Skewness	0.10	0.69	0.14	1.27	0.14	1.09	0.19	0.11
Kurtosis	1.53	2.00	2.20	2.81	1.70	2.91	2.18	1.94
Observations	52	52	52	51	52	52	52	52

Source: Authors' Calculations

Ghana has a strong trade profile, with significant exports like gold, crude petroleum, cocoa, coconuts, and cashews [7,48]. The country also imports essential goods like refined petroleum, cars, rice, and delivery trucks [7]. Regarding trading partners, Ghana engages in robust trade relationships with several key nations. Notably, China emerges as a prominent partner for imports and exports, underlining the significance of Sino-Ghanaian trade relations [49–51]. The United States, the European Union, India, and the United Arab Emirates are prominent trading partners [50]. This suggests diversified trade ties with countries from different regions, further highlighting Ghana's participation in the global trade network. Ghana's trade profile showcases a balanced mix of natural resource-based exports and essential goods and commodities imports. Overall, Ghana's trade profile reflects active participation in the global economy and strategic partnerships with nations across different continents.

Fig. 3 illustrates the trend of trade in Ghana from 1970 to 2020. Trade was relatively stagnant and declining before 1980. However, from 1980 to 2000, a consistent upward trend led to a peak in 2000. Post-2000, the trend in Ghana's trade took a different trajectory. From 2001 to 2020, trade experienced a general state of fluctuation. This era witnessed fluctuations in the volume of international trade. This fluctuating pattern suggests that Ghana's trade landscape became more dynamic, influenced by various economic factors, policies, and global market conditions. Ghana's trade performance, trade to GDP ratio, fluctuated significantly in the past four years, reaching as high as 76.82% in 2019 but dropping sharply to 38.52% in 2020 due to the impact of the COVID-19 pandemic. The trend is being analyzed by dividing it into exports and imports.

Fig. 4 illustrates the trend of Ghana's export and import sectors. The sector grew from US$2,562.4 million in 2003 to US$13,752 million in 2013, with a 22% average growth rate. Imports, however, expanded more rapidly, resulting in an increased trade gap. The composition of exports remained stable, with primary goods constituting 86%, including dominant mineral export gold (96.6% of mineral export revenue and 37.1% of overall export revenue in 2013). Cocoa beans, the second-largest earner before oil production, decreased to 11% by 2013. Gold's share increased to 19%, becoming the highest export earner in 2013 (28.3%), followed by oil. Timber exports declined to 1.2% in 2013 due to significant deforestation. This analysis underscores Ghana's reliance on primary goods, emphasizing the need for diversification and sustainable practices, particularly in forestry, for long-term export viability.

For imports, Ghana's imports surged from $0.41 billion to $3.35 billion, underscoring the country's impressive economic growth and development. This substantial increase indicated Ghana's expanding economy and growing need for imported goods. This trend continued from 2000 to 2009. However, from 2009 to 2019, Ghana's import trajectory witnessed fluctuations. In 2019, imports were valued at $26.91 billion, a 15.88% upswing from the preceding year. The period of fluctuation from 2009 to 2019 indicates the dynamic nature of Ghana's import landscape, influenced by various economic factors and policies; the subsequent years brought about notable import-value shifts, reflecting broader economic changes. In 2020, the COVID-19 pandemic wrought a sharp decline in imports, which plummeted by a staggering 53.68% to $12.46 billion. The decline in imports in 2020 was a direct consequence of the COVID-19 pandemic. It resulted in a slowdown in Ghana's GDP growth, petroleum revenue shortfalls, and disruptions in supply chains, significantly impacting the import sector. Moreover, 85.4% of importing firms reported difficulties obtaining supplies, further exacerbating the decline. As of 2021, there was a remarkable rebound, with imports surging by an impressive 81.13% to $22.58 billion. This rebound reflects both economic recovery efforts and the adaptation of businesses to the pandemic-induced challenges. However, as of 2022, imports saw a modest decrease of 19.26% to $18.23 billion. This shift may indicate a more measured approach to imports in light of the evolving economic landscape. In conclusion, Ghana's import trends reflect its dynamic economy, influenced by internal and external factors. The significant fluctuations observed over the years highlight the country's adaptability and resilience in economic challenges, including the unprecedented impact of the COVID-19 pandemic.

The current study further investigates these findings by first evaluating the impact of trade on the composite sustainable development index and subsequently scrutinizing its effect on environmental sustainability, a crucial dimension of the composite sustainability index measured using Ghana's C02 emissions. The composite sustainable development index is pivotal in this study, acting as a comprehensive metric to gauge Ghana's overall sustainability performance. This index amalgamates various dimensions of sustainability, including environmental, economic, and social factors, into a single composite measure. This approach allows for a holistic assessment of Ghana's progress towards sustainable development, offering a nuanced understanding beyond one-dimensional indicators. By examining the impact of trade on this composite index, the study delves into the intricate dynamics between trade inflows and the overarching sustainability objectives of the nation. This meticulous investigation aims to uncover an overall adverse relationship and the specific dimensions of sustainability that are

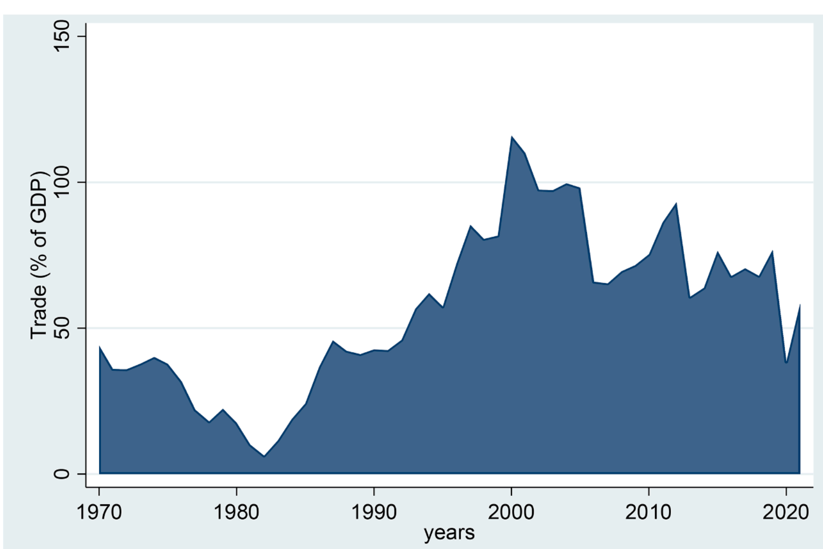

Fig. 3. Trend of Trade in Ghana, 1970 to 2022.

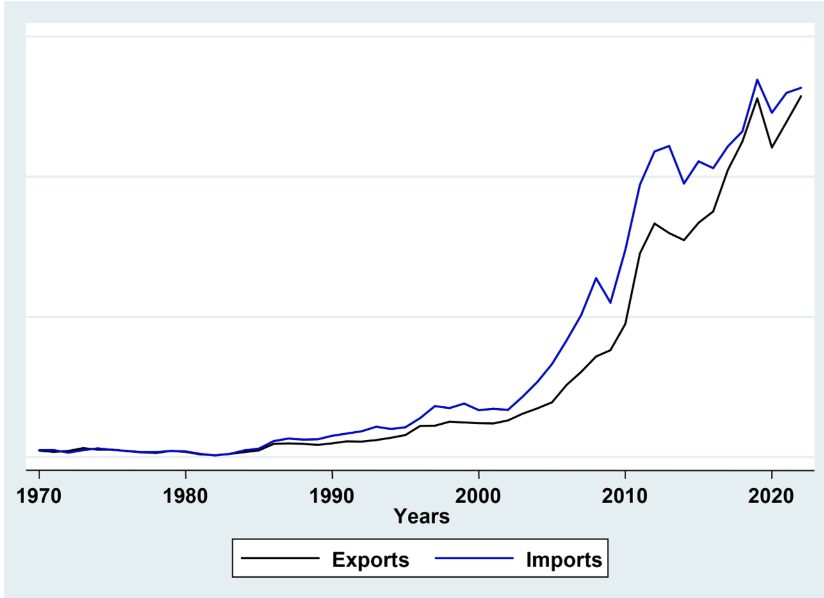

Fig. 4. Trend of Trade in Ghana's Export and Imports, 1970 to 2022.

predominantly affected by trade.

3.2. Stationarity and Co-integration analysis

We employ the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) tests to assess the stationarity of the variables at both their levels ($I(0)$) and first differences ($I(1)$). The presence of a long-run relationship is determined using the ARDL bound co-integration test.

The results in Panels A and B of Table 3 show that most variables exhibit a significant level of stationarity when tested in their first differences, as indicated by the significance level. Notably, variables such as TRADE, FDI, ENERGY, GDP, NRR, and EDUCATION demonstrate strong stationarity in their first differences. This suggests that these variables are integrated of order one, $I(1)$, implying that they exhibit a stable behavior when analyzed in their changes from period to period.

Table 3
Stationarity and ARDL Bound Co-integration results.

Variable	Level I(0)		First Difference I(1)	
	Intercept	Intercept/ Trend	Intercept	Intercept/ Trend
Panel A: ADF Test Results				
ANS	-4.129***	-4.602***		
CO2	-2.608*	-3.445**		
TRADE	-1.570	-1.954	-7.815***	-7.763***
FDI	-1.066	-1.938	-7.924***	-7.846***
ENERGY	-1.988	-3.453*	-7.512***	-7.498***
URBAN	-0.944	-0.920	-5.482***	-5.632***
GDP	2.565	-0.978	-4.466***	-6.300***
NRR	-5.048***	-5.976***		
EDUCATION	-1.520	-1.244	-4.387***	-4.354***
Panel B: PP Test Results				
ANS	-4.162***	-4.652***		
CO2	-2.330	-3.318*	-9.257***	-9.312***
TRADE	-1.428	-1.871	-7.900***	-7.849***
FDI	-1.076	-1.958	-8.401***	-8.380***
URBAN	-1.452	-1.421	-5.539***	-5.645***
GDP	1.877	-0.965	-4.473***	-6.279***
NRR	-5.044***	-5.894		
EDUCATION	-1.709	-1.508	-4.119***	-4.092***
Panel C: ARDL Bound Co-integration Test				
	5% Critical Bound			
	I(0) 2.710		I(1) 4.309	
Model 1 F = 5.803				
Model 2 F = 6.950				

* $p < .10$, ** $p < .05$, *** $p < .01$

The ARDL bound co-integration test results show an F-statistic of 5.803 for Model 1 and 6.950 for Model 2, which surpasses the critical bound value of 2.710 at the 5% significance level (Table 3, Panel C). This implies the rejection of the null hypothesis ($\mathbf{H}_0$: no level relationship) and suggests a long-run co-integrating relationship among the variables.

The stationarity and co-integration analysis outcomes collectively provide valuable insights into the dynamics of the variables in the sustainable development and environmental quality models. The stationarity of variables in their first differences implies that short-term dynamics and shocks can be reliably captured and analyzed. Furthermore, co-integration signifies a stable and enduring relationship among the variables, offering a foundation for exploring short- and long-run interactions.

3.3. Impact of trade on sustainable development of Ghana

The empirical results in Tables 4 and 5 shed light on the short-run and long-run relationships between trade, environmental quality, and sustainable development in Ghana. These findings provide critical insights into the complex interplay of factors influencing Ghana's journey towards achieving sustainable development objectives.

The study found a positive relationship between trade and sustainable development in Ghana, both in the short-run ($\alpha = 0.513$, t = 3.13) and long-run ($\beta = 0.333$, t = 4.77). Trade activities have a significant impact on sustainable development trends. However, it is essential to note that while trade promotes economic sustainability, it harms Ghana's environmental sustainability by increasing environmental degradation in the short term ($\alpha = 0.249$, t = 2.91) and the long term ($\beta = 0.330$, t = 5.62).

The positive impact of trade on sustainable development in Ghana is mainly due to its economic dimension. Trade enhances allocative efficiency, fosters economic growth [52,53], and helps address unemployment and poverty issues [8,54,55]. The findings align with the comparative advantage theory of trade and underscore the potential of trade to positively influence social welfare, as consumers and producers

Table 4
Short-Run ARDL model.

Variables	(1) C02-Model	(2) SD-Model
ANS(-1)	0.179 (0.159)	0.655 (0.167)***
TRADE	-0.026 (0.089)	-0.114 (0.155)
TRADE(-1)	0.249 (0.085)***	0.513 (0.163)***
FDI	0.006 (0.002)***	0.006 (0.003)
FDI(-1)	-0.002 (0.002)	-0.014 (0.004)***
ENERGY	0.024 (0.129)	0.049 (0.118)
GDP	0.001 (0.008)	-0.018 (0.013)
GDP(-1)	-0.002 (0.007)	0.042 (0.011)***
URBAN	4.926 (4.365)	
NRR		-0.078 (0.116)
NRR(-1)		0.312 (0.125)**
EDUCATION		-0.947 (0.368)**
EDUCATION(-1)		0.222 (0.539)
Constant	-1.695 (13.964)	-46.117 (16.222)
R-square	0.783	0.791
Adjusted R-square	0.720	0.657
Root MSE	5.407	8.027
Log-likelihood	-148.474	-152.414
F-Statistics	12.50	5.90
P-value	0.0000	0.0000

Note: Standard errors are in parentheses.
* $p < .10$, ** $p < .05$, *** $p < .01$

Table 5
Long-Run ARDL model.

Variables	(1) C02-Model	(2) SD-Model
TRADE	0.330 (0.058)***	0.333 (0.069)***
FDI	0.006 (0.002)***	-0.007 (0.003)**
ENERGY	0.187 (0.147)	0.041 (0.100)
GDP	-0.004 (0.003)	0.020 (0.004)***
URBAN	-1.463 (1.583)	
NRR		0.196 (0.139)
EDUCATION		-1.021 (0.250)***
Error Correction Term (ECT)(-1)	-0.840 (0.303)***	-1.194 (0.232)***
R-square	0.699	0.780
Adjusted R-square	0.604	0.638
Root MSE	4.673	8.027
Log-likelihood	-132.235	-152.414

Note: Standard errors are in parentheses.
* $p < .10$, ** $p < .05$, *** $p < .01$

benefit from the expansion of trade activities. Trade openness provides access to international markets, high-quality goods at lower costs, competition, innovation, and specialization. All of these contribute to economic expansion and productivity. Ghana's export sector primarily relies on natural resources and agriculture, generates significant foreign exchange, and drives job creation. In 2021, Ghana's exports were valued at $17 billion, supporting employment in labor-intensive industries like mining, cocoa processing, and the agricultural sector, engaging approximately 57% of the employed population [56]. The discovery of oil in 2007 contributed to middle-income status in 2010 and reached a peak growth of 14.4% [57]. On the other hand, the import sector sustains local industries through imports like refined petroleum, cars, and essential goods such as medicaments, rice, and wheat. These imports stimulate job creation across transport, healthcare, agriculture, and manufacturing sectors, enhancing economic sustainability.

However, it is essential to acknowledge that the emphasis on the economic dimension of sustainability, without considering the environmental dimension, reflects a scenario of weak sustainability. The concepts of weak and strong sustainability are central to understanding this apparent contradiction. Weak sustainability emphasizes the substitutability between the economy and the environment, often prioritizing economic growth over environmental concerns. On the other hand, strong sustainability highlights the intrinsic value of the environment and the limitations on the substitutability between natural and manufactured capital [58]. The findings pointing to the positive impact of trade on sustainable development in Ghana, despite its adverse environmental effects, suggest a leaning towards weak sustainability, where economic gains are prioritized over environmental preservation. Sustainable development requires a balance between economic, social, and environmental factors. A shift towards strong sustainability may be necessary to ensure long-term sustainability.

In Ghana, there are several instances of leaning toward weak sustainability. Cocoa production is a quintessential example of an economic activity that, while generating substantial economic benefits, comes with its share of environmental costs. Ghana is the second largest cocoa exporter globally, underscoring this industry's economic significance to the nation's economy. Apart from fertilizers, the cocoa industry relies heavily on pesticides and herbicides [59]. These chemical agents protect cocoa trees from pests and weeds, ensuring healthy and productive crops. However, the widespread application of these chemicals also brings about environmental challenges, particularly concerning pollution [59]. Pesticides, including insecticides, fungicides, and herbicides, contain active ingredients designed to target specific pests and diseases. While effectively safeguarding cocoa crops, their use can lead to unintended environmental consequences: improper application or excessive use of pesticides results in the contamination of soil and water resources. The improper disposal of pesticide containers is a critical issue in cocoa-producing regions. If not handled correctly, these containers can release residues into the environment, leading to soil and water pollution. This pollution, in turn, can adversely affect local ecosystems and potentially harm human health, particularly for those directly involved in cocoa farming.

Additionally, the use of herbicides to control weeds in cocoa plantations presents its own set of environmental challenges. Herbicides often contain chemicals that can persist in the environment, potentially affecting non-target plants and organisms [60]. This can disrupt the balance of local ecosystems and have long-term consequences for biodiversity. Furthermore, deforestation and habitat destruction are common occurrences in regions where cocoa production is prevalent. To establish cocoa plantations, natural habitats are often cleared, leading to the loss of valuable biodiversity and disruption of local ecosystems. The prioritization of economic benefits from cocoa production over environmental costs exemplifies the concept of weak sustainability. The overreliance on chemical agents and the environmental consequences of their use reflects a scenario where economic gains are emphasized at the expense of environmental preservation. This highlights the need for more effective policies and practices to mitigate the environmental impacts of cocoa production and to ensure a balance between economic growth and environmental preservation in line with strong sustainability.

The case of gold mining in Ghana also exemplifies the trade-off between economic prosperity and environmental degradation, reflecting the principles of weak sustainability. Ghana's significant gold production contributes to its economy but has led to extensive environmental damage, including deforestation, soil erosion, water and air pollution, and mercury contamination [61]. These environmental impacts underscore the prevalence of weak sustainability, prioritizing economic gains over environmental preservation. The use of toxic chemicals and the unregulated nature of some mining activities, such as "galamsey," further emphasize the weak sustainability approach, as they lead to widespread environmental degradation [61]. On the other hand, strong sustainability emphasizes the intrinsic value and the preservation of the environment. In Ghana's gold mining context, a shift towards strong sustainability would entail implementing stringent environmental regulations, responsible mining practices, and proactive measures to rehabilitate mined areas. This would help mitigate the environmental costs of gold mining while ensuring the environment's and local communities' long-term well-being. This highlights the need for a balanced approach to ensure economic and environmental sustainability. While the expansion of exports, particularly in the case of gold and cocoa, brings substantial economic benefits, it also imposes significant environmental costs. Therefore, achieving a balance between economic growth and environmental preservation is imperative for the sustainable development of Ghana.

The debate on sustainable development, on weak and strong sustainability, has been explored in the literature. Pelenc et al. [58] conducted a study focusing on the differences between weak and strong sustainability. The study revealed the importance of natural capital in supporting human life and well-being, advocating for a shift towards strong sustainability to preserve these vital elements. The study highlighted the limitations on the substitutability between natural and manufactured capital, emphasizing the intrinsic value of the environment and the necessity of prioritizing ecological preservation over economic gains. Similarly, Beck and Ferasso [62] conducted a literature review analysis that explored how stakeholder capitalism can contribute to achieving Sustainable Development Goals. The study highlighted the need for better integrating the environmental dimension in stakeholder capitalism and urban sustainability, aligning with strong sustainability principles prioritizing the preservation of ecological value. These studies have contributed to the ongoing discourse on sustainable development, urging for a more balanced and integrated approach that acknowledges the irreplaceable contributions of natural capital to human welfare and ecological balance.

In conclusion, Ghana's trade presents environmental drawbacks while fostering sustainable development. This aligns with an economic-focused sustainability approach, leaning towards weak sustainability. It highlights the prevailing prioritization of economic gains over environmental concerns. The study emphasizes the necessity for a balanced strategy harmonizing economic progress with environmental preservation.

3.4. Discussion of findings

The empirical results in Tables 4 and 5 contribute valuable insights into the intricate relationships between trade, environmental quality, and sustainable development in Ghana, offering essential perspectives on the nation's progress toward sustainable development objectives. The study's findings first affirm a significant positive relationship between trade and sustainable development in Ghana, both in the short and long-run. The coefficient estimates for trade in both time frames underscore the substantial impact of trade activities on sustainable development trends. However, it is important to note that while trade significantly promotes economic sustainability, it has a noticeable adverse impact on Ghana's environmental sustainability in the form of enhancing environmental degradation, both in the short term and the long term.

The positive impact of trade on sustainable development in Ghana, despite its negative environmental effects, can be explained by emphasizing the economic dimension of sustainability. In this context, trade plays a crucial role in enhancing allocative efficiency. The benefits of trade openness, including access to international markets, high-quality goods at lower costs, competition, innovation, and specialization, all contribute to economic expansion and productivity. The findings of the current study align with previous studies such as Oppong-Baah et al. [8], Yeboah and Anning [54], and Anetor et al. [55], emphasizing the crucial role of trade in fostering economic growth, employment, and poverty alleviation in Ghana. Also, our results are consistent with Oppong-Baah et al. [8], who found that trade openness positively impacted economic growth in Ghana and Nigeria. Similarly, the positive impact of economic openness on employment creation, as highlighted by Yeboah and Anning [54], resonates with the current findings, indicating the positive association between trade and job opportunities. Additionally, Anetor et al.'s [55] insights into the positive and significant impact of trade on poverty reduction align with the emphasis on economic sustainability in the present study.

The noticeable adverse impact of trade on Ghana's environmental sustainability aligns with the theoretical framework emphasizing the pollution intensity of certain industries, such as gold, cocoa, and oil, in Ghana, known as the heavy pollution industries, and their contribution to environmental degradation [18]. The study underscores the substantial reliance of Ghana's economy on trade, with trade as a percentage of GDP averaging 56.44 from 1970 to 2021. This dependence comes with potential environmental ramifications, as explained by the *pollution haven hypothesis*, which suggests that pollution-intensive industries tend to concentrate in developing countries with lenient environmental regulations [18], a phenomenon observed in Ghana due to its rich natural resources and weak regulatory institutions [63]. The study's findings are confirmed by similar research by Asongu and Odhiambo [12], Ertugrul et al. [64], and Udeagha and Ngepah [65]. For example, Asongu and Odhiambo [12] found that increased trade openness positively influences CO_2 emissions in Sub-Saharan Africa. Ertugrul et al. [64] identified real income, energy consumption, and trade openness as key determinants of carbon emissions in developing countries. Udeagha and Ngepah [65] revealed that trade openness deteriorates environmental quality in the long run in South Africa.

The current study makes nuanced contributions by adopting a more integrated approach, utilizing a composite sustainable development index for comprehensive evaluation. This approach considers environmental, economic, and social factors, providing a comprehensive understanding that goes beyond the sole focus on economic growth and CO_2 emissions in previous studies. By delving into the complexities of the short-run and long-run relationships, the study provides a deeper understanding of how trade dynamics influence sustainable development in the Ghanaian context. It emphasizes the specific mechanisms through which trade enhances allocative efficiency, economic growth, and overall sustainability, enriching the existing literature on the subject. In summary, while building upon the foundations laid by previous studies, the current research adds granularity to the understanding of the trade-sustainable development nexus in Ghana, shedding light on the multifaceted dynamics that drive the nation's progress toward its sustainability goals.

3.5. Implication for policymakers

The findings of the study support the notion of weak sustainability in Ghana; this, therefore, reveals the need for strong sustainability. Policymakers in Ghana should focus on promoting strong sustainability practices in various economic sectors, such as trade, cocoa production, and gold mining. This can be achieved by promoting eco-friendly technologies and methods, implementing policies that protect natural resources, and promoting ecosystem conservation. For instance, promoting and supporting organic and agroecological farming methods in the cocoa industry can reduce the reliance on chemical agents and minimize environmental impacts. Similarly, adopting responsible mining practices, such as reclamation of mined areas in the mining sector, can help mitigate environmental degradation.

Policymakers should establish and enforce strict environmental regulations to minimize the negative environmental impacts of economic activities. Monitoring and enforcing compliance with these regulations is crucial to ensure their effectiveness. In the gold mining sector, regulations should be implemented to control the use of toxic chemicals like mercury and cyanide, prevent deforestation, and mitigate soil and water pollution.

Furthermore, policymakers should prioritize the well-being of communities affected by environmental degradation. They should invest in social welfare programs, education, and healthcare initiatives to improve living conditions and mitigate the negative impacts of environmental degradation. Revenue from mining and agriculture should fund community development, healthcare, and education in affected areas.

Collaboration between government agencies, private sector organizations, and local communities is necessary to address public problems related to environmental degradation and sustainable development. Policymakers should create dialogue, negotiation, and cooperation platforms to develop joint solutions and policies. In collaboration with mining and agricultural companies, the government should engage local communities in decision-making processes and consider their concerns and needs.

To promote a culture of sustainability and responsible stewardship of natural resources, policymakers should invest in environmental education and awareness campaigns. This could involve supporting environmental education programs in schools, universities, and communities and promoting media campaigns that raise public awareness about environmental issues and the importance of sustainable practices.

Finally, policymakers should focus on diversifying the economy to reduce overreliance on sectors with significant environmental impacts, such as mining and agriculture. This could involve promoting the development of other sectors, such as renewable energy, tourism, and technology, which have the potential to generate economic growth while minimizing environmental degradation. By diversifying the economy, Ghana can reduce the pressure on natural resources and ecosystems and create new opportunities for sustainable development.

3.6. Model diagnostics

Tables 6 and 7 display the results of the model diagnostics, providing crucial insights into the robustness of our regression models. The LM test for autoregressive conditional heteroskedasticity (ARCH) yielded non-significant p-values for both Model 1 (CO2) and Model 2 (SD), suggesting the absence of heteroskedasticity. This implies that the variance of the error term remains constant across observations, a vital assumption. The Breusch-Pagan / Cook-Weisberg test for heteroskedasticity further supported this finding, with p-values exceeding conventional thresholds. Similarly, Durbin's alternative test for autocorrelation produced non-significant p-values for both models, indicating no systematic correlation in the error terms. This is a crucial assurance for reliable inference.

Additionally, the Breusch-Godfrey LM test for autocorrelation confirmed the robustness of these results. The Doornik-Hansen test for multivariate normality provided non-significant p-values for both models, indicating that the errors follow a normal distribution. This is a pivotal assumption for reliable inference in regression analysis. The Cumulative Sum (CUSUM) and Cumulative Sum of Squares (CUSUMSQ) tests demonstrated the stability of the coefficients in both models, further enhancing our confidence in the robustness of the estimated regression models over time.

To assess the independence of the variables, we conducted a pairwise (linear) correlation analysis and evaluated the variance inflation factor (VIF). As shown in Table 7, the results confirm the absence of multicollinearity among the variables. The pairwise correlation coefficients

Table 6
Model diagnostics.

Test Performed	(1) C02-Model Statistic	(2) SD-Model Statistic
LM test for autoregressive conditional heteroskedasticity (ARCH)	0.528 (0.467)	0.150 (0.698)
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity	0.04 (0.833)	1.03 (0.309)
Durbin's alternative test for autocorrelation	0.001 (0.973)	1.008 (0.315)
Breusch-Godfrey LM test for autocorrelation		1.691 (0.193)
Doornik-Hansen test for multivariate normality		3.688 (0.158)
CUSUM/CUSUMSQ	Stable	Stable

Note: *p*-values are in parentheses.

Table 7
Multicollinearity results.

Panel A: Pairwise correlation analysis

	ANS	TRADE	FDI	URBAN	ENERGY	GDP
ANS	1.00					
TRADE	0.40	1.00				
FDI	0.28	0.35	1.00			
URBAN	-0.01	0.18	-0.28	1.00		
ENERGY	-0.12	-0.35	-0.55	0.18	1.00	
GDP	0.36	0.36	0. 51	-0.43	-0.64	1.00

Panel B: Variance inflation factor (VIF)

GDP	3.36
FDI	2.15
ENERGY	1.70
URBAN	1.54
TRADE	1.41

between all variables with sustainable development (i.e., ANS) were consistently below 0.7, indicating a lack of strong linear relationships among the variables. This signifies their relative independence. Furthermore, the VIF values for all variables were substantially below the threshold of 10, affirming that multicollinearity is not a significant concern in the model. This means the variables can effectively predict each other without facing collinearity problems.

In summary, the model diagnostics collectively provide robust support for the validity and reliability of our estimated regression models. The absence of significant issues such as heteroskedasticity, autocorrelation, and multicollinearity among the variables signifies that the assumptions underlying our regression models are met and strengthens our confidence in the results and conclusions drawn from the analysis.

4. Conclusion

The findings of this study underscore the importance of considering the concepts of weak and strong sustainability in understanding the complex relationship between trade, sustainable development, and environmental quality in Ghana. The study's findings affirm a significant positive relationship between trade and sustainable development in Ghana, both in the short and long-run. However, it is important to note that while trade significantly promotes economic sustainability, it has a noticeable adverse impact on Ghana's environmental sustainability. Despite its negative environmental effects, the positive impact of trade on sustainable development in Ghana suggests a leaning towards weak sustainability, where economic gains are prioritized over environmental preservation.

Given the pivotal role of natural resources like cocoa, gold, and oil in Ghana's economic growth, addressing existing deficits in natural resource governance is imperative. The United Nations Development Program (UNDP)'s ongoing initiative to examine and enhance Ghana's natural resource governance performance and its alignment with the Sustainable Development Goals (SDGs) presents a timely opportunity for transformative change. Targeted policy recommendations are proposed to address this nuanced dynamic of the impact of trade on sustainable development, as policies should be guided by sustainable development [66]. Hence, policies should focus on promoting eco-friendly technologies and methods, implementing policies that protect natural resources, and promoting ecosystem conservation. Policymakers should establish and enforce strict environmental regulations to minimize the negative environmental impacts of economic activities. This includes monitoring and enforcing compliance with these regulations to ensure their effectiveness. Policymakers should invest in environmental education and awareness campaigns to promote a culture of sustainability and responsible stewardship of natural resources. This could involve supporting environmental education programs in schools, universities, and communities and promoting media campaigns that raise public awareness about environmental issues and the importance of sustainable practices. Finally, policymakers should focus on diversifying the economy to reduce overreliance on sectors with significant environmental impacts, such as mining and agriculture. Drawing from global best practices, Ghana can chart a course toward sustainable development, ensuring a balance between economic prosperity and environmental preservation. By adopting these recommendations, policymakers can develop more effective strategies to address the challenges posed by trade and economic growth on Ghana's environmental sustainability. This will require a shift towards strong sustainability, which emphasizes the intrinsic value of the environment and the limitations on the substitutability between natural and manufactured capital.

In terms of limitations, this study is based on secondary data and could not determine the causes of the failure to include environmental preservation in the pursuit of economic gains. Furthermore, the narrow geographical focus solely on Ghana restricts the generalizability of findings to a broader African or resource-intensive context. Future research should endeavor to augment analyses with primary data sources to address these constraints. Particularly, investigating the oversight of environmental preservation amidst the pursuit of economic gains, notably within sectors such as mining and cocoa, is a pertinent avenue for deeper insights. Expanding the study's scope to encompass Sub-Saharan Africa or broader African nations would enhance the generalizability of the findings to the broader African context. Future studies could also explore the implications of adopting a strong sustainability approach. This could involve examining the potential benefits and challenges of prioritizing environmental preservation and identifying strategies for achieving a balance between these two objectives.

Compliance with ethical standards

Complied with all ethical standards and requirements.

CRediT authorship contribution statement

Malik Dawuda Kindo: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Aziz Abdulai Adams:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jamal Mohammed:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

None.

Data availability

A publicly available dataset from the World Development Indicators of the World Bank and the International Monetary Fund was used for the analysis. The dataset can be accessed from https://databank.worldbank.org/source/world-development-indicators (for all variables except FDI) and https://www.imf.org/en/Data (for only FDI).

Funding

None.

Acknowledgments

We want to thank Professor Imhotep Paul Alagidede of the Wits Business School, University of the Witwatersrand, Johannesburg, South Africa, for his invaluable comments and suggestions at the initial stages of the manuscript development. The comments and suggestions helped shape this work.

References

[1] CEIC. Ghana gold production 2022. https://www.ceicdata.com/en/indicator/ghana/gold-production (accessed September 1, 2023).
[2] GhanaWeb. Ghana attained a historic production of 1.1 million metric Tonnes of cocoa beans 2021.
[3] Ministry of Energy. The Annual report on the petroleum funds for 2020. 2021.
[4] M Ibrahim, P. Alagidede, Effect of financial development on economic growth in sub-Saharan Africa, J. Policy Model 40 (2018) 1104–1125.
[5] Forestry Commission. Forestry commission annual report 2017. 2017.
[6] D Sakyi, R Commodore, EE. Opoku, Foreign direct investment, trade openness and economic growth in Ghana: an empirical investigation, J. Afric. Bus. 16 (2015) 1–15.
[7] I Okyere, L. Jilu, The impact of export and import on the economic growth of Ghana, Eur. J. Bus. Manag. 12 (2020) 130–138.
[8] T Oppong-Baah, Y Bo, C Twi-Brempong, EO Amoah, NA Prempeh, M. Addai, The impact of trade openness on economic growth: The case of Ghana and Nigeria, J. Human Resour. Sustain. Stud. 10 (2022) 142–160.
[9] Ozigbu JC. Trade integration and economic well-being: evidence from generalised methods of moments (GMM) in the d-8 countries. Sustainable Development 2022; 6:64–75.
[10] E Duodu, ST. Baidoo, How does the quality of institutions affect the impact of trade openness on Ghana's economic growth? Cogent Econ. Finance 8 (2020) 1812258.
[11] P Enu, ED Havi, E. Hagan, The IMPACT OF FOREIGN TRADE ON ECONOMIC GROWTH IN Ghana (1980-2012), Int. J. Acad. Res. Econ. Manag. Sci. 2 (2013) 174.
[12] S Asongu, NM. Odhiambo, Trade and FDI thresholds of CO2 emissions for a Green economy in sub-Saharan Africa, Int. J. Energy Sect. Manage. 15 (2021) 227–245.
[13] L Dauda, X Long, CN Mensah, M Salman, KB Boamah, S Ampon-Wireko, et al., Innovation, trade openness and CO2 emissions in selected countries in Africa, J. Clean. Prod. 281 (2021) 125143, https://doi.org/10.1016/j.jclepro.2020.125143.
[14] H Sun, L Enna, A Monney, DK Tran, E Rasoulinezhad, F. Taghizadeh-Hesary, The long-run effects of trade openness on carbon emissions in sub-Saharan African countries, Energies 13 (2020) 5295, https://doi.org/10.3390/en13205295.
[15] Zerbo E. CO2 emissions, growth, energy consumption and foreign trade in Sub-Sahara African countries. 2015.
[16] M. Kohler, CO2 emissions, energy consumption, income and foreign trade: a South African perspective, Energy Policy 63 (2013) 1042–1050, https://doi.org/10.1016/j.enpol.2013.09.022.
[17] J. Jung, The nexus between institutional quality and global market structure: export versus FDI, Mathematics 10 (2022) 4629.
[18] W Antweiler, BR Copeland, MS. Taylor, Is free trade good for the environment? Am. Econ. Rev. 91 (2001) 877–908.
[19] T Tsurumi, S. Managi, Health-related and non-health-related effects of PM2. 5 on life satisfaction: Evidence from India, China and Japan, Econ. Anal. Policy 67 (2020) 114–123.
[20] B Saboori, J Sulaiman, S. Mohd, Economic growth and CO2 emissions in Malaysia: a co-integration analysis of the environmental Kuznets curve, Energy Policy 51 (2012) 184–191.
[21] A Cherp, C George, C. Kirkpatrick, A methodology for assessing national sustainable development strategies, Environ. Plann. C Gov. Policy 22 (2004) 913–926.
[22] AL. Wenden, Discourses on poverty: Emerging perspectives on a caring economy, World Q. 29 (2008) 1051–1067.
[23] DK Twerefou, K Danso-Mensah, GA. Bokpin, The environmental effects of economic growth and globalization in Sub-Saharan Africa: A panel general method of moments approach, Res. Int. Bus. Finance 42 (2017) 939–949.
[24] A Jalil, M. Feridun, The impact of growth, energy and financial development on the environment in China: a co-integration analysis, Energy Econ. 33 (2011) 284–291.
[25] MB Shrestha, GR. Bhatta, Selecting appropriate methodological framework for time series data analysis, J. Finance Data Sci. 4 (2018) 71–89, https://doi.org/10.1016/j.jfds.2017.11.001.
[26] RF Engle, CW. Granger, Co-integration and error correction: representation, estimation, and testing, Econometrica (1987) 251–276.
[27] S. Johansen, Estimation and hypothesis testing of co-integration vectors in Gaussian vector autoregressive models, Econometrica (1991) 1551–1580.
[28] MH Pesaran, Y Shin, RP. Smith, Pooled mean group estimation of dynamic heterogeneous panels, J. Am. Stat. Assoc. 94 (1999) 621–634.
[29] MH. Pesaran, The role of economic theory in modeling the long run, Econ. J.. 107 (1997) 178–191.
[30] A Banerjee, JJ Dolado, JW Galbraith, D. Hendry, Co-Integration, Error Correction, and the Econometric Analysis of Non-Stationary Data, Oxford University Press, 1993.
[31] M Afzal, MS Farooq, HK Ahmad, I Begum, MA. Quddus, Relationship between school education and economic growth in Pakistan: ARDL bounds testing approach to co-integration, Pak. Econ. Soc. Rev. (2010) 39–60.
[32] M Song, Y. Zhou, Quantitative analysis of foreign trade and environmental efficiency in China, Emerg. Market. Finance Trade 52 (2016) 1647–1660.
[33] E Akbostanci, S Türüt-Aşik, GI. Tunç, The relationship between income and environment in Turkey: is there an environmental Kuznets curve? Energy Policy 37 (2009) 861–867, https://doi.org/10.1016/j.enpol.2008.09.088.
[34] SS. Sharma, Determinants of carbon dioxide emissions: Empirical evidence from 69 countries, Appl. Energy 88 (2011) 376–382, https://doi.org/10.1016/j.apenergy.2010.07.022.

[35] KM. Wang, Modelling the nonlinear relationship between CO2 emissions from oil and economic growth, Econ. Model. 29 (2012) 1537–1547, https://doi.org/10.1016/j.econmod.2012.05.001.
[36] BH. Hamilton, Does entrepreneurship pay? An empirical analysis of the returns to self-employment, J. Polit. Econ. 108 (2000) 604–631.
[37] J Baek, Y Cho, WW. Koo, The environmental consequences of globalization: A country-specific time-series analysis, Ecol. Econ. 68 (2009) 2255–2264, https://doi.org/10.1016/j.ecolecon.2009.02.021.
[38] K Jayanthakumaran, Y. Liu, Openness and the environmental Kuznets curve: evidence from China, Econ Model 29 (2012) 566–576, https://doi.org/10.1016/j.econmod.2011.12.011.
[39] C Kirkpatrick, C George, SS. Scrieciu, The Implications of Trade and Investment Liberalisation for Sustainable Development, Review of Literature, Manchester, 2004.
[40] H Iwata, K Okada, S. Samreth, Empirical study on the environmental Kuznets curve for CO2 in France: the role of nuclear energy, Energy Policy 38 (2010) 4057–4063, https://doi.org/10.1016/j.enpol.2010.03.031.
[41] J He, J Deng, M. Su, CO2 emission from China's energy sector and strategy for its control, Energy 35 (2010) 4494–4498, https://doi.org/10.1016/j.energy.2009.04.009.
[42] RS Franklin, M. Ruth, Growing up and cleaning up: The environmental Kuznets curve redux, Appl. Geogr. 32 (2012) 29–39, https://doi.org/10.1016/j.apgeog.2010.10.014.
[43] K Jayanthakumaran, R Verma, Y. Liu, CO2 emissions, energy consumption, trade and income: A comparative analysis of China and India, Energy Policy 42 (2012) 450–460, https://doi.org/10.1016/j.enpol.2011.12.010.
[44] J Baek, WW. Koo, A dynamic approach to the FDI-environment nexus: the case of China and India, J. Int. Econ. Stud. 13 (2009) 87–108.
[45] Y Xing, CD. Kolstad, Do lax environmental regulations attract foreign investment? Environ. Resour. Econ. (Dordr.) 21 (2002) 1–22.
[46] S. Hossain, An econometric analysis for CO2 emissions, energy consumption, economic growth, foreign trade and urbanization of Japan, Low Carbon Econ. 3 (2012) 92–105, https://doi.org/10.4236/lce.2012.323013.
[47] World Bank. The environmental toll of gold mining in Ghana 2017. https://www.worldbank.org/en/news/feature/2017/07/20/the-environmental-toll-of-gold-mining-in-ghana (accessed July 4, 2023).
[48] EY Gbolonyo, Determinants of Export Diversification in Ghana, University of Cape Coast, 2019. Thesis.
[49] E Yeboah, Y Jing, A. Lucy, Overview of Ghana's Export and Import, FDI inflow and outflow: is there any connection between its trading partners and foreign investing countries? Asian J. Interdiscip. Res. 3 (2020) 1–14, https://doi.org/10.34256/ajir2031.
[50] A. Danquah, The Role of Regional and Bilateral Trade Agreements in the Economic Development of Ghana: Case: Ghana-China Relations, Lahti University of Applied Sciences, 2017. Thesis.
[51] J Hou, X Fu, P. Mohnen, The impact of China–Africa trade on the productivity of African firms: evidence from Ghana, Eur. J. Dev. Res. 34 (2022) 869–896, https://doi.org/10.1057/s41287-021-00381-5.
[52] R Wacziarg, KH. Welch, Trade liberalization and growth: New evidence, World Bank Econ. Rev. 22 (2008) 187–231.
[53] Frankel JA, Romer DH. Trade and growth: An empirical investigation. 1996.
[54] E Yeboah, L. Anning, Investment in Ghana: an overview of FDI components and the impact on employment creation in the Ghanaian economy, Econ. Manag. Sustain. 5 (2020) 6–16, https://doi.org/10.14254/jems.2020.5-1.1.
[55] FO Anetor, E Esho, G. Verhoef, The impact of foreign direct investment, foreign aid and trade on poverty reduction: evidence from Sub-Saharan African countries, Cogent Econ. Finance 8 (2020) 1737347, https://doi.org/10.1080/23322039.2020.1737347.
[56] Nxumalo M, Raju D. Structural transformation and labor market performance in Ghana. 2020.
[57] Aryeetey E, Baah-Boateng W. Understanding Ghana's growth success story and job creation challenges. Helsinki: the United Nations University World Institute for Development Economics Research (UNU-WIDER); 2015. https://doi.org/10.35188/UNU-WIDER/2015/029-4.
[58] Pelenc J, Dubois JL. Innovating in the link between strong sustainability and the capability approach: the role of critical natural capital in human development. International conference of Human Development and Capability Approach, 2011.
[59] SA Takyi, O Amponsah, DKB Inkoom, GA. Azunre, Sustaining Ghana's cocoa sector through environmentally smart agricultural practices: an assessment of the environmental impacts of cocoa production in Ghana, Africa Review 11 (2019) 172–189, https://doi.org/10.1080/09744053.2019.1635416.
[60] M Mehdizadeh, W Mushtaq, SA Siddiqui, S Ayadi, P Kaur, S Yeboah, et al., Herbicide residues in agroecosystems: fate, detection, and effect on non-target plants, Rev. Agric. Sci. 9 (2021) 157–167.
[61] AK Mensah, IO Mahiri, O Owusu, OD Mireku, I Wireko, EA. Kissi, Environmental impacts of mining: a study of mining communities in Ghana, Appl. Ecol. Environ. Sci. 3 (2015) 81–94.
[62] D Beck, M. Ferasso, How can stakeholder capitalism contribute to achieving the sustainable development goals? A cross-network literature analysis, Ecol. Econ. 204 (2023) 107673.
[63] D Adams, S Ullah, P Akhtar, K Adams, S. Saidi, The role of country-level institutional factors in escaping the natural resource curse: Insights from Ghana, Resour. Policy 61 (2019) 433–440, https://doi.org/10.1016/j.resourpol.2018.03.005.
[64] HM Ertugrul, M Cetin, F Seker, E. Dogan, The impact of trade openness on global carbon dioxide emissions: Evidence from the top ten emitters among developing countries, Ecol. Indic. 67 (2016) 543–555, https://doi.org/10.1016/j.ecolind.2016.03.027.
[65] MC Udeagha, N. Ngepah, Does trade openness mitigate the environmental degradation in South Africa? Environ. Sci. Polluti. Res. 29 (2022) 19352–19377, https://doi.org/10.1007/s11356-021-17193-z.
[66] H Khan, IU Khan, From growth to sustainable development in developing countries: a conceptual framework, Environ. Econ. 3 (2012) 23–31.