Print ISSN: 2765-6934 / Online ISSN: 2765-7027
AJBE website: http://accesson.kr/ajbe
Doi: 10.13106/ajbe.2024.vol14.no3.23

Impact of Energy Consumption, FDI and Trade Openness on Carbon Emissions in Ivory Coast

Ange Aurore KADI[1], Liang LI[2], David Dauda LANSANA[3], Joseph FUSEINI[4]

Received: April 10, 2024. Revised: April 27, 2024. Accepted: May 14, 2024.

Abstract

Purpose: The study focuses on the impact of Foreign Direct Investment (FDI), trade openness, and energy consumption on carbon dioxide emissions in the Ivory Coast. It aims to quantitatively evaluate the effects of FDI, energy consumption, and trade openness on CO_2 emissions in Ivory Coast. **Research design, data, and methodology:** The research uses an econometric framework and the Autoregressive Distributed Lag (ARDL) model to analyze time-series data from 1980 to 2021 between these factors. **Results:** The analysis revealed that FDI significantly impacts the carbon dioxide emissions, FDI showed a negative impact on carbon emissions in the long-run equilibrium term. Also, energy consumption impacted CO_2 emissions in the long-run equilibrium term. **Conclusion**: To mitigate the upsurge of CO_2 emissions in the Ivorian context, concrete policy, including enactment and adherence to strict environmental regulations, adoption and prioritization of eco-friendly products and technologies, and investment in renewable energy infrastructure are recommended. The study contributes to the global discussion on sustainable development by offering a model for similar assessments in other emerging nations facing simultaneous economic growth and environmental conservation challenges.

Keywords: CO_2 emissions, FDI, Trade Openness, Energy Consumption, Ivory Coast

JEL Classification Code: C12, C32, F18, F41, P18

1. Introduction

Economists, decision-makers, and the general public are increasingly concerned with the economic analysis of the nexus between international trade and CO_2 emissions. Comparably, international trade has been tremendously boosted by the WTO reconstruction of the GATT. Creating the "Trade Facilitation Agreement" (TFA) is the most current tactic. In the field of trade economics, Adam Smith and David Ricardo previously illustrated the mutual give-and-take of global trade in their absolute. The theory of advantage and the theory of comparative advantage, correspondingly. These findings suggest that emerging countries with flexible economic strategies benefit from mutual trade advantages.

1 First Author. Ange Aurore Kadi. School of Business, Nanjing University of Information Science and Technology University, China. Email: awaleykadi3@gmail.com
2 Corresponding Author. Liang Li, School of Business, Nanjing University of Information Science and Technology, China, Email: llcwllcw@hotmail.com
3 Third Author. David Dauda Lansana. School of Business, Nanjing University of Information Science and Technology, China, Email: davema168@gmail.com
4 Forth Author. Joseph Fuseini. School of Management Science and Engineering, Nanjing University of Information Science and Technology, China, Email: josephfuseini270@gmail.com

It is also important to note that there is a growing global awareness of carbon emissions and the need for legislation to reduce their generation. One of the main contributors to global warming is carbon emissions. There has been a significant increase in CO_2 emissions since the beginning of the industrial revolution. Due to economic advancements, these emissions are still rising at an accelerating rate.

According to Kamara, foreign direct investment (FDI) increased averagely from US$14.9 billion each year between 2001 and 2005 to US$30.3 billion between 2006 and 2010. Undoubtedly, industrialized nations appear to be more responsible for CO_2 emissions. This is just one of the numerous explanations for why developed economies are the focus of most of this kind of research. According to Lindmark, a significant increase in carbon emissions occurs when a nation is developing. The two main strategies for reducing CO_2 emissions that prior research has presented are technological means or economic ones, such as raising fuel prices or enacting levies to restrict the use of fossil fuels. Though they might lower carbon emissions, these technologies and policies might harm growth. Being able to control the variables that could affect CO_2 emissions is one potential remedy. However, this is only possible if a clear correlation exists between these variables.

It is critical to comprehend how economic activity affects the environment at a time when environmental degradation and global warming provide severe obstacles to sustainable development. Ivory Coast, a growing nation driven by rising trade openness and FDI, is faced with choosing between pursuing environmental protection and economic development. This thesis explores the complex link between FDI, commercial openness, and CO_2 emissions in this West African country, highlighting how economic globalization influences environmental results. Like many developing countries, Ivory Coast has been experiencing an increase in direct investment from abroad and economic liberalization in recent years. FDI refers to the investment made by foreign entities, such as multinational corporations, in domestic companies or infrastructure, while trade openness refers to the degree of access a country has to international trade. The link between FDI, trade openness, and carbon emissions is a topic of considerable interest due to the increasing concerns about climate change and the need for sustainable development. The consequences of FDI and trade openness on carbon emissions on the Ivory Coast can be examined from two perspectives: the positive and negative effects.

On the positive side, FDI and trade openness can contribute to technological advancements, knowledge transfer, and increased investment in sustainable production techniques. As an illustration, foreign direct investment brings about novel technologies and methodologies that can aid in mitigating carbon emissions. Moreover, commercial openness enables the acquisition and implementation of eco-friendly technologies and methodologies from nations with a stronger environmental awareness. On the negative side, FDI and increased trade can expand energy-intensive industries that heavily rely on fossil fuels, contributing to higher carbon emissions. For instance, industries such as manufacturing and transportation might experience growth, resulting in increased pollutant emissions unless proper environmental regulations and measures are in place.

Therefore, the effect of FDI and trade openness on carbon emissions in Ivory Coast is contingent upon various factors, including the nature of investments, the stringency of environmental regulations, and the extent to which businesses adopt sustainable practices. It's worth noting that addressing carbon emissions and promoting sustainable development requires a holistic approach, including policy interventions, technological advancements, and international cooperation. Governments should prioritize developing and implementing robust environmental policies to ensure that FDI and trade openness contribute to reducing, rather than exacerbating, carbon emissions in Ivory Coast.

To achieve sustainable development, nations like Ivory Coast must understand the intricate relationship between FDI and trade openness on carbon emission. This West African nation presents a unique chance to examine the conflicts between the pursuit of FDI and environmental preservation due to its diverse biological landscape and swiftly expanding economy.

This study measures the short- and long-term correlations between FDI, trade liberalization, energy consumption, and CO_2 emissions. It investigates the directional causality among these variables using an econometric framework combining the ARDL technique with VECM. By doing this, it hopes to clarify the circumstances in which trade liberalization and foreign direct investment (FDI) can support environmental sustainability and economic growth, providing insightful information to decision-makers who must negotiate the challenges of environmental stewardship and global economic integration.

It also looks at the country's complex relationship between foreign investment and market openness on CO_2 emissions and how that relationship affects the nation's future development. (Like many developing countries, lvory Coast is at a turning point in its history where efforts to achieve economic growth often have negative environmental effects, chiefly from carbon emissions. It is critical to understand the impact of CO_2 emissions given the continued appeal of the lvory Coast to foreign direct investment and trade openness.)

The urgency of this research shows the necessity of balancing environmental and economic goals in light of climate change. This thesis adds to the larger discussion on

sustainable development by thoroughly analyzing the nexus amid FDI, trade openness, and CO_2 emissions in the context of Ivory Coast. It emphasizes the critical role of policy interventions, technological advancements, and international cooperation in balancing environmental preservation and economic development. This essay aims to add to the current discourse on sustainable development in Ivory Coast by thoroughly examining the connection between foreign direct investment and trade openness on carbon emissions.

2. Literature review

A growing body of scholarship has explored the correlation between greenhouse gas emissions and economic growth, mostly due to the escalating environmental deterioration. The theoretical and empirical literature is based on the well-known notion called the Environmental Kuznets Curve (EKC). The EKC theory posits that environmental deterioration initially increases during the early stages of development and, after that reduces as economic growth progresses (Stern, 2004). This statement provides evidence for the U-shaped curve of the EKC, which suggests that in the early stages of industry, increasing pollution levels are associated with higher productivity in a country.

However, as the country progresses, additional measures to mitigate environmental deterioration and technological advancements will reduce contamination. There is limited research that explicitly examines the connection between carbon emissions and economic expansion has been a subject of extensive research. Most studies have concentrated primarily on economic growth and energy usage, with carbon emissions rarely included.

This study will focus on two categories of research. The first category includes studies that analyze the relationship between carbon dioxide emissions and economic development. The second category includes studies investigating the relationship between energy utilization, the economy's expansion, and the release of carbon dioxide.

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2.1. Energy Consumption and CO_2 Emissions

Soytas et al. (2006) focused on examining the Granger causality connection among earnings, energy utilization, and carbon discharges rather than assessing the existence of the EKC hypothesis. Labor and gross fixed capital served as the study's intermittent factors. The results affirmed that energy usage leads to carbon emissions in the US, but there is no enduring correlation between income and carbon discharges. Halicioglu (2008) explored the correlation between energy usage, earnings, international trade, and carbon emissions in Turkey from 1960 to 2005. Through the boundaries test, the study identified two types of enduring correlations among the variables. Initially, energy utilization, earnings, and foreign trade contribute to carbon emissions; secondly, energy usage, earnings, and foreign trade influence carbon discharges.

The goal of Zhang and Cheng's (2009) study was to ascertain whether there was a Granger causation relationship between China's economic growth, carbon emissions, and energy consumption. The study used time series data covering the years 1960–2007 and included capital and urban population as intermittent variables The outcomes from the multivariate model revealed that energy usage leads to carbon emissions, while economic expansion drives energy consumption. Apergis and Payne (2009) examined the presence of a Granger causality link between carbon footprint, energy use, and economic growth across six Central American countries from 1971 to 2004. They observed that a reciprocal causal association exists between emissions and energy consumption.

From 1980 to 2007, Pao and Tsai (2011) examined the dynamic connection between energy usage, production, and pollutant discharges in Brazil. The results confirmed the presence of the energy-income and emissions-income inverted U connection. This suggests that energy use and environmental harm increase with income, stabilise, and then decline. The Granger causality results showed that, income, energy use, and emissions are all influenced in both directions. Li et al. (2017) looked at the relationship between China's CO_2 emissions, economic expansion, and three specific forms of fossil energy consumption—coal, gas, and oil—from 1965 to 2015. The Johansen cointegration test results confirm that the variables have a long-term relationship. The results of the VECM demonstrate a two-way causal relationship between GDP and petrol use and between coal usage and CO_2 emissions. The findings also demonstrated a unidirectional causal relationship between GDP oil consumption and CO_2 as well as GDP and oil consumption.

Using data from 1960 to 2013, Cetin et al. (2018) investigated trade openness, energy consumption, economic development, and financial development are the primary determinants of carbon emissions. The outcomes additionally demonstrated the long- and short-term validity of the EKC hypothesis for Turkey. Moreover, a long-term causal relationship between economic expansion and CO_2 emissions was discovered. Khoshnevis and Dariani (2019) examined the inducing link between 1980 and 2014 for Asian nations regarding trade openness, economic growth, energy consumption, and carbon emissions. Panel Granger causality tests and the pooled mean group (P.M.G.) technique were used in the investigation. The Pedroni panel cointegration test results indicated that the variables may

have a long-term link. The Granger causality findings indicated a mutual causal relationship among urbanization, economic expansion, and CO_2 emissions.

Vo and Le's (2019) research aimed to determine the causal association among carbon dioxide emissions, energy usage, renewable energy, population, and economic variables across five ASEAN member nations from 1971 to 2014. The findings indicated that only for Indonesia, Myanmar, and Malaysia is there a long-term association between the factors. It is also found that whereas Malaysia and Indonesia do not affirm the EKC hypothesis, Myanmar does. In Malaysia, Thailand, and the Philippines, the premise of neutrality among the variables was established; however, in Indonesia, a one-way causal relationship was shown between economic development, carbon emissions, and energy consumption. Myanmar has a one-way causal relationship between population growth, energy consumption, economic growth, and renewable energy. The link between energy consumption, carbon emissions, and economic growth in Togo was examined by Mathieu et al. (2019). The study discovered a lengthy link between the variables using the ARDL model. The impact of energy consumption and economic growth on carbon dioxide emissions for seventy nations between 1994 and 2013 was evaluated by Osobajo et al. (2020). The variables may have a long-term association, according to the research. According to the pooled OLS and fixed method analysis, energy use and economic boom benefited carbon emissions. For the 11 Guangdong-Hong Kong-Mocao cities, Fong et al. (2022) investigate the connection between energy use and unfavorable CO_2 emissions for the years 2010–2016. The results showed that the GBA cities' average efficiency was 0.708, except for Macao SAR, Shenzhen, and Hong Kong SAR, all of which had an efficiency of 1 for the course of the study.

2.2. FDI and Carbon Emission

Much discussion has surrounded how foreign direct investment (FDI) affects environmental deterioration. Balsalobre-Lorente et al. (2018) investigate in their study "What is the influence of economic expansion, sustainable power generation, and environmental assets on CO_2 discharges?" the effect of investment from abroad on greenhouse gas emissions. They suggest many facets and a complex link between FDI and CO_2 emissions. Pao and Tsai (2011) provide insightful information about how foreign direct investment affects environmental circumstances in developing countries.

The research by Tang and Tan (2015) demonstrated the application of Granger causality examination in analyzing the correlation between FDI and CO_2 discharges. Ren et al (2014) examined how foreign direct investment influences carbon dioxide emissions in oil-exporting nations, focusing on emissions calculation based on territory rather than consumption. Their findings indicate that FDI can lower emissions with appropriate environmental measures. Granger causality assessments were employed by Omri, et al. (2015) in their research to unveil a causal connection between ecological degradation and economic expansion in the MENA region. Zhang and Zhou (2016) demonstrated that FDI in specific sectors has led to a notable rise in CO_2 emissions.

The influence of overseas direct investment on China's environment was analyzed by Liang (2006). According to the analysis, there was a clear relationship between increased FDI and rising CO_2 emissions. This suggests that China's most polluting industries were associated with foreign investment. In their 2018 study, Solarin and Al-Mulali investigated how foreign direct investment (FDI) affected environmental degradation indices, with a particular emphasis on CO_2 emissions. The study found that FDI initially harmed the environment. However, FDI begins to favorably impact the improvement of environmental circumstances as the host country's economy grows and develops.

The link between the BRIC countries' financial and economic growth and the degradation of the environment was assessed by Tamazian et al. (2009). The study discovered a favorable association between increased foreign direct investment (FDI) levels and better environmental standards, even when economic expansion initially increase pollution levels, including CO_2 emissions. The use of greener technologies could be the reason for this development.

The financial and economic development and environmental degradation of BRIC countries were assessed by Tamazian et al. (2009). Higher levels of foreign direct investment (FDI) correlate positively with improved environmental standards, even while economic expansion initially raises pollution levels, particularly CO_2 emissions. More ecologically friendly technologies may be the reason for this improvement. With an emphasis on Turkey, Seker, et al. (2015) mainly looked at how FDI affected environmental conditions. The results showed that while FDI had a negative short-term impact on environmental conditions, it had a positive long-term impact. This suggests a transitional phase during which rapid industrialization led to increased emissions first, and then improvements gradually occurred.

In 2010, Pao and Tsai. demonstrated that FDI significantly contributed to rising CO_2 emissions in these rapidly developing nations, primarily due to energy-intensive businesses. Also, except for Russia, for which data was available from 1992 to 2007, Pao and Tsai (2010) sought to ascertain the connection between carbon

emissions, energy utilization, and foreign direct investment in the BRIC countries from 1980 to 2007. The study's conclusions seemed to confirm the EKC theory by indicating that carbon emissions are elastic in energy consumption over time. The findings also demonstrated a one-way causal relationship between output and FDI and a bidirectional relationship between emissions and FDI.

The study in 2011 by Elliott and Zhang. This study looks at Chinese cities and evaluates how foreign direct investment (FDI) affects environmental change and economic growth, with a focus on CO_2 emissions. In a 2002 study Xing and Kolstad. This study looks at the connection between foreign direct investment (FDI) inflow, the severity of environmental regulations in various nations, and the impact this has on CO_2 emissions. The research's conclusions offer insightful information that is relevant to emerging countries.

In 2017, a study named "The Impacts of Environmental Regulations on Competitiveness" was carried out by Dechezleprêtre and Sato. This paper thoroughly examines how environmental regulations affect foreign direct investment (FDI) flows and, in turn, greenhouse gas emissions. It focuses on this relationship's regulatory aspect.

Zugravu-Soilita (2017) studied the effects of foreign direct investment (FDI) on pollution levels, focusing on CO_2 emissions across various countries.

2.3. Trade Openness and Carbon Emissions

Several studies have created theory- and empirically-based models to analyze how trade liberalization affects the environment. A crucial consideration in creating trade policy is how global trade affects environmental sustainability. Between 1990 and 2011, the simultaneous equation model examined the effect of CO_2 emissions on trade openness and other variables for 14 Middle Eastern and North American (MENA) countries. The conclusion indicated a reversed and statistically insignificant correlation between free trade and environmental contamination in these economies.

Shahbaz et al. (2017) analyzed 105 countries using the fully modified ordinary least squares (FMOLS) technique, collecting data from 1980 to 2014 and categorizing them into global, high-income (developed), middle-income (developing), and low-income (underdeveloped) categories. The research unveiled an inverted U-shaped correlation between trade liberalization and environmental condition across all categories. Similarly, Shahbaz et al. (2013) found that heightened trade openness results in increased levels of research and development linked to FDI, thereby decreasing pollution.

According to the Sohag et at. findings, there is a 0.3% decrease in CO_2 emissions for every percentage increase in trade. However, for low-income, middle-income, and all sample countries, the results were not conclusive. Managi et al. (2009) demonstrated that while global trade has a counterintuitive effect in rich economies, it raises emissions in less developed ones.

The effects of trade's scale and composition have been attributed to this increase in emissions. Jayanthakumaran et al. investigated the correlation among actual earnings, worldwide commerce, CO_2 emissions, and sulphur dioxide (SO_2) particles using industrial data from different Chinese regions from 1997 to 2007. They determined that global trade decreases greenhouse gas discharges by boosting earnings and enhancing consumer expenditure on eco-friendly products.

The correlation between CO_2 emissions and economic develpment in the United Kingdom was studied based on the cointegration, error correction model, and Granger causality test. There was evidence of both short- and long-term causation between the variables. Additionally, it discovered a unidirectional causal relationship between the international trade ratio and final energy use, CO_2 emissions, and the real gross domestic product (RGDP). The findings also showed that the connection between GDP and CO_2 was shaped like an inverted U. trade openness can raise CO_2 emissions, and the EKC hypothesis was validated in the UK.

Using panel data cointegration analysis, Akin investigated the effects of income, energy consumption, and foreign commerce on CO_2 emissions. The findings showed a strong, favorable correlation. The results imply that, at least temporarily, a unidirectional causal relationship exists between CO_2 emissions and trade openness.

Ozturk and Acaravci (2013) discovered a strong and positive correlation between CO_2 and trade openness in Turkey, however, Boutabba suggested that trade openness has a detrimental impact on CO_2 levels in India.

Furthermore, some research with conflicting findings have linked CO_2 emissions to trade openness Jalil. Omri et al. (2011) revealed a unidirectional causal relationship between trade openness and CO_2 emissions. Modus operandi Managi et al. assessed the total impact of commerce on environmental quality using instrumental variables. The results showed that, while advanced economies responded differently, non-advanced economies saw a decrease in pollution due to foreign trade; this difference in outcome was ascribed to the magnitude and makeup of trade impacts.

Conversely, trade liberalization will eventually reduce CO_2 emissions. Al Mamun et al. (2014) showed that CO_2 emissions are reduced by 0.3% when the proportionate change in trade is held constant together with all other explanatory variables. Interestingly, the results for middle-class, low-income, and survey-completed countries were equivocal.

3. Methodology

3.1. Research Design

The study utilizes a quantitative research methodology to empirically evaluate the connections between foreign direct investment (FDI), trade openness, energy consumption, and carbon dioxide (CO_2) emissions in Ivory Coast. This design enables the investigation of cause-and-effect linkages and the verification of hypotheses obtained from the theoretical framework. The analysis encompasses a time series dataset that extends from 1980 to 2021, enabling the examination of both immediate and prolonged patterns and impacts.

3.2. Data

Table 1 displays the information covering the Ivory Coast timeframe from 1980 to 2021. The data concerning carbon emissions, energy usage, FDI, and trade openness factors were obtained from identical sources. The data for foreign direct investment, commercial openness, and carbon emissions were all sourced from the World Bank.

Table 1: Data Variables Description and Sources

Variables	Description	Source
CO_2 emissions(CO_2)	CO_2 emissions (metric tons) (% of GDP)	World bank
Energy Consumption (Energy)	Primary energy consumption (kWh/person)	World bank
Foreign Direct Investment (FDI)	Foreign direct investment, net inflows (BoP, current US$)	World bank
Trade openness	Trade (% of GDP)	World bank

3.4. Theoretical Framework

The paper's theoretical framework is based on environmental economics and trade theory, specifically emphasizing the correlation between trade openness, carbon emissions, and foreign direct investment (FDI). It is based on the EKC theory, which postulates an inverse U-shaped link between economic growth and environmental deterioration. According to this hypothesis, pollution and environmental degradation rise in the early phases of economic expansion. Still, when more resources are devoted to decreasing pollution, the tendency reverses beyond a particular income per capita level.

The framework also considers views about trade openness and foreign direct investment, taking into account how these factors may both aggravate and lessen environmental degradation. The pollution haven theory, which postulates that businesses relocate their polluting operations to nations with low environmental restrictions, is weighed against the notion that FDI may introduce greener technology and practices. The hypothesis for trade openness takes into account the composition and technique effects, which could result in a cleaner environment through the adoption of greener technologies and a shift in the industrial structure towards less polluting sectors, as well as the scale effect, which could increase emissions due to higher production and consumption.

3.5. Empirical modeling

The empirical modeling aims to evaluate these hypotheses in the context of Ivory Coast, with a particular emphasis on how trade openness and FDI affect CO_2 emissions while accounting for energy use. The following mental representation of the model is possible:

$$\Delta CO2_t=\alpha+\sum_{i=1}^{p} p\phi_i \Delta CO2_{t-i}+\sum_{i=1}^{q} q\theta_{j1}\Delta FDI_{t-j} +\sum_{k=1}^{y}\theta_{k2}\Delta Energy_{t-k}+\sum_{l=1}^{s}\theta_{l3}\Delta TO_{t-l}+\gamma CO2_{t-1} +\delta_1 FDI_{t-1}+\delta_2 Energy_{t-1}+\delta_3 TO_{t-1}+\epsilon_t$$

Where:

1. Δ denotes the difference operator. CO_{2t} is the level of CO_2 emissions at time t.FDI_t is the level of foreign direct investment at time t. $Energy_t$ is the energy consumption at time t. TO_t is the trade openness at time t. α is the intercept. ϕ_i, θ_{j1}, θ_{k2}, θ_{l3} are short-run coefficients for the lags of the dependent and independent variables. γ, δ_1, δ_2, δ_3 are long-run coefficients for the dependent and independent variables. p, q, r, s are the number of lags included for each variable in the model.ϵ_t is the error term.

Unit Root test

For levels: $\Delta y_t=\alpha+\beta_t+\gamma y_{t-1}+\sum_{i=1}^{p}\delta i\Delta y_{t-i}+\epsilon_t$

For first differences: $\Delta^2 y_t= \alpha+\beta t+\gamma\Delta y_{t-1}+\sum_{i=1}^{p}\delta i\Delta^2 y_{t-i}+\epsilon_t$

Where:

1. yt represents the time series variable at time t (which is CO_2, Energy, FDI, or TO). Δdenotes the first difference operator. α is the constant (intercept) term. βt is the trend component. γ is the coefficient on the lagged level of the series (for the levels equation) or lagged first difference (for the first difference equation). δi are the coefficients on the lagged first differences of the series. p is the number of lagged first difference terms included in the regression. ϵ_t is the error term.

ADRL Model

ECM: $\Delta y_t=\beta_0+\beta_1 t+\beta_2\Delta FDI_t+\beta_3\Delta FDI_{t-1}+\alpha EC_{t-1}+\epsilon_t$

Where:

2. Δy_t represents the change in the dependent variable at time t .β_0 is the constant term (C), in this case. β_1 is the coefficient for the time trend (@TREND). β_2 is the coefficient for the first difference of FDI at time t. β_3 is the coefficient for the first difference of FDI at time $t-\mathbf{1}$.α is the coefficient for the error correction term (CointEq(-1)), which measures the adjustment back towards long-term equilibrium after short-term changes. EC_{t-1} is the error correction term from the previous period. ϵ_t is the error term or the residual of the equation at time t.

Short run test:

$$\Delta y_t = \beta_0 + \beta_1 t + \beta_2 CO2_{t-1} + \beta_3 ENERGY_t + \beta_4 \Delta FDI_{t-1} + \beta_5 TO_t + \beta_6 TO_{t-1} + \beta_7 \Delta FDI_{t-1} + \beta_8 \Delta FDI_{t-1} + \epsilon_t$$

Where:

3. Δyt is the change in the dependent variable at time t. β_0 (C) is the constant term. β_1 (@TREND) is the coefficient for the time trend. β_2 is the coefficient for the lagged value of CO_2. β_3 is the coefficient for the current value of ENERGY. β_4 is the coefficient for the lagged value of FDI. β_5 is the coefficient for the current value of TO. β_6 is the coefficient for the lagged value of TO. β_7 is the coefficient for the first difference of FDI. ϵ_t is the error term at time t.

T Bound test:

$$CO2_t = \alpha + \beta_1 FDI_t + \beta_2 Energy_t + \beta_3 TO_t + \epsilon_t$$

4. CO_{2t} represents the level of CO_2 emissions at time *t*. FDI_t is the level of Foreign Direct Investment at time *t*. $Energy_t$ represents the energy consumption at time *t*. TO_t is the measure of Trade Openness at time *t*. α is the intercept term. β_1, β_2, and β_3 are the long-run coefficients for FDI, Energy Use, and Trade Openness, respectively. ϵ_t is the error term.

F Bound Test:

$$\Delta y_t = \alpha + \sum_{i=1}^{p} \phi_i \Delta y_{t-i} + \sum_{j=1}^{q} \theta_{j1} \Delta x_{j,t} + \gamma y_{t-1} + \sum_{i=1}^{p} q\ \delta_j x_{j,t-1} + \epsilon_t$$

5. Δy_t is the change in the dependent variable at time t. α is the intercept. ϕ_t are the coefficients for the lags of the dependent variable. $\Delta x_{j,t}$ are the changes in independent variables at time t.θ_{j1} are the coefficients for the short-run dynamics of the model. y_{t-1} is the lagged dependent variable, where γ captures its coefficient for the long-run relationship. $x_{j,\,t-1}$ are the lagged independent variables, where δ_j are their coefficients in the long-run relationship. ϵ_t is the error term.

3.6. Estimation Technique

The Autoregressive Distributed Lag (ARDL) approach to cointegration is the estimation technique used in your thesis. It captures the short-term dynamics through an error correction model (ECM) and enables the analysis of long-term relationships between the variables of interest. Either I(0), I(1), or a mix of both can be employed as regressors; however, the ARDL technique works best with small sample sizes.

In addition, the thesis tests if there is a long-term equilibrium link between CO_2 emissions, FDI, trade openness, and energy consumption using the Bounds Testing technique to cointegration inside the ARDL framework. The short-term dynamics are recorded by the

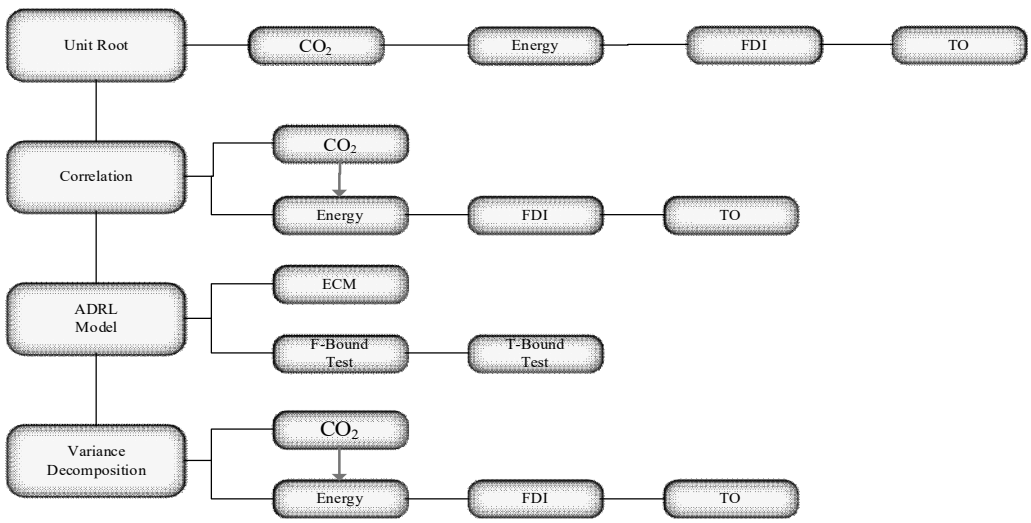

Figure 2: Estimation Technique

ECM, which shows the rate of adjustment towards equilibrium, and the long-term coefficients are computed once cointegration has been achieved.

To investigate the direction of causation among the variables and understand how trade openness, energy consumption, and FDI affect CO_2 emissions over time.

Several diagnostic tests, including tests for autocorrelation, heteroscedasticity, and model specification, are performed to verify the dependability and resilience of the regression findings. Furthermore, sensitivity studies are conducted to assess the resilience of the results to other model parameters and variable definitions.

A comprehensive investigation of the connection between FDI and trade openness and CO_2 emissions is made possible by combining theoretical foundations and empirical estimating approaches. This study provides insightful information about the mechanisms involved and helps Ivory Coast policymakers make choices.

4. Results and Discussions

4.1. Unit Root Test

The study examines the stationarity of various variables in a series of data. CO_2 emissions show a t-statistic of -3.1216, rejecting the null hypothesis of a unit root at the 5% significance level. Energy consumption shows a t-statistic of -2.2406, indicating it is not stationary at levels. FDI shows a t-statistic of -0.6342, indicating it is not stationary at levels. Trade Openness shows a t-statistic of -1.997727, indicating it cannot reject the null hypothesis. The series becomes stationary after differencing. The results suggest that the data is not stationary at any specific level. Stationarity at Levels: Only the CO_2 emissions exhibit evidence of stationarity at levels, indicating that its statistical characteristics remain constant throughout time without the need for any differencing.

Stationarity after differencing: Energy consumption, foreign direct investment (FDI), and trade openness are non-stationary at their original levels but exhibit stationarity after differencing. This suggests that their first differences are not influenced by time.

Table 2: Unit Root Test

Variables	ADF (Levels) t-Statistics	ADF (Levels) Prob**	ADF (D) t-Statistics	ADF (D) Prob**
CO_2	-3.1216	0.0327	-8.0356	0.0000
Energy	-2.2406	0.1957	-6.1642	0.0000
FDI	-0.6342	0.9890	-8.4066	0.0000
TO	-1.9977	0.2867	-6.9474	0.0000

4.2. Correlation Matrix

The correlation value of 0.6360 indicates a moderate to significant positive association between CO_2 emissions and energy consumption. This means that as energy consumption rises, so do CO_2 emissions. The negative coefficient of -0.2739 reveals a weak inverse correlation between CO_2 and FDI. There is a negative correlation between FDI and carbon dioxide (CO_2) emissions, meaning that as FDI increases, CO_2 emissions tend to decrease significantly.

The coefficient of 0.2399 for CO_2 and TO as expressed in Table 3, indicates a weak positive correlation. This means that when trade openness improves, there is a slight tendency for CO_2 emissions also to increase. The correlation value of 0.1075 indicates a fragile positive relationship between energy and FDI. This demonstrates a minor association between higher FDI and higher energy usage. The correlation coefficient between energy usage and trade openness is 0.0183, indicating a negligible linear link between the two variables. The negative coefficient of -0.6604 indicates a robust inverse link between FDI and TO. This means that trade openness decreases as FDI increases, and vice versa.

Table 3: Correlation Matrix

Variables	Co_2	Energy	FDI	TO
Co_2	1			
Energy	0.6360	1		
FDI	0.2739	0.1075	1	
TO	0.2399	0.0183	-0.6604	1

4.3. ADR Error Correction Model

The study reveals a negative trend in CO_2 emissions when other variables are held constant, indicating a decreasing trend over time as shown in Table 4. The short-run effect of FDI on CO_2 emissions is positive but not statistically significant. The lag of FDI's first difference positively correlates with CO_2 emissions, indicating a significant positive effect from the previous period.

The coefficient (-0.8819) is highly significant, indicating the speed of adjustment towards long-run equilibrium after a shock. The ECM analysis reveals a substantial and enduring connection between CO_2 emissions and the variables considered. Furthermore, a mechanism in operation rectifies any deviations from the long-term equilibrium. There are also short-term changes happening, especially when considering the delayed impact of FDI on CO_2 emissions.

Table 4: ADR Error Correction Model

Variable	Coefficient	Standard Error	t-Statistic	Probability
C (Constant)	-0.0910	0.0240	-4.1589	0.0002
TREND	-0.0020	0.0009	-2.2298	0.0329
D(FDI)	9.7500	6.0600	1.6102	0.1172
D(FDI(-1))	1.8600	7.8900	2.3633	0.0244
CointEq(-1)	-0.8819	0.1133	-7.7819	0.0000

4.4. ADRL Results

The study reveals significant short-term relationships between CO_2 emissions, lagged FDI changes, and current changes in energy consumption, as shown in Table 5. The current change in FDI is not statistically significant at conventional levels, while the lagged change in FDI is statistically significant at the 5% level. Trade openness and energy consumption also show no significant relationship at conventional levels. The presence of a statistically significant correction term ($CO_2(-1)$*) suggests that deviations from long-run equilibrium are corrected each period, also Energy consumption and FDI impact CO_2 emissions in the long-run equilibrium term.

According to the T-bound and F-bound test results, the F-statistic (13.8417) exceeds the upper critical value for all significance levels. This indicates that there is empirical support for a stable and enduring relationship among the variables in the model.

Table 5: ADRL Short Run and Long Run Results

Variables	Coefficient	Standard Error	t-Statistic	Probability
C	-0.0999	0.1435	-0.6962	0.4913
TREND	-0.0020	0.0021	-0.9241	0.3623
$CO_2(-1)$ *	-0.8819	0.1315	-6.7076	0.0000
ENERGY	0.0003	5.0100	6.0426	0.0000
ENERGY(-1) *	-2.1400	1.0700	-1.9877	0.0555
TO	-0.0004	0.0016	-0.2474	0.8062
TO(-1) *	0.0004	0.0006	1.2408	0.1538
D(FDI)	9.7500	6.6800	1.4607	0.1538
D(FDI(-1)) *	1.8600	9.1100	2.0452	0.0491

4.5. Diagnostics Test

The Breusch-Godfrey Serial Correlation LM Test is a statistical test used to detect the presence of serial correlation in a dataset. The F-statistic value is 1.3019, and the Prob** is 0.2869 as displayed in Appendix 1

This test examines whether there is a correlation between the residuals in a regression model. It indicates that there is no statistically significant autocorrelation. Jarque-Bera Test F-statistic is 1.8769 and Prob** is 0.3912

The Jarque-Bera test is a statistical test used to determine if a given set of sample data exhibits the same skewness and kurtosis as a normal distribution. Here, the test statistic is small, and the p-value is large, suggesting that the data does not exhibit substantial deviation from normality. Heteroskedasticity Test (ARCH) has a t-statistics of 0.8853 a prob** of 0.3529

The ARCH test is employed to identify the existence of heteroskedasticity, which refers to the situation where the variance of the error terms changes with time. A p-value of 0.3529, as observed in this example, indicates insufficient evidence to support the presence of heteroskedasticity. Therefore, we cannot reject the null hypothesis that the error components of the model have constant variance. Based on the cusum test Appendix 2 results, the regression model does not seem to have any issues with serial correlation, departure from normality, or heteroskedasticity. This conclusion is drawn from the high p-values seen in all three tests. This suggests that the model satisfies the required assumptions.

4.6. Ramsey RESET Test

According to the RESET test, the model does not seem to have any important variables left out, and the functional form appears suitable as displayed in Appendix 3.

4.7. Variance Decomposition

The table breaks down the variance of forecast errors in CO_2 emissions into proportions that can be attributable to its unexpected changes and unexpected changes in the ENERGY, FDI, and TO (Trade Openness) variables over a 10-period period. Here is the analysis (which is also displayed in Appendix 4:

In period 1, the entirety (100%) of the discrepancy between the predicted and actual values of CO_2 emissions is attributed to the influence of its unexpected events. This is anticipated, as the effects of unexpected events in other variables will become apparent in subsequent periods.

During period 2, the proportion of variance attributed to CO_2 reduces slightly to 98.18560%. At the same time, the impact of shocks related to ENERGY, FDI, and TO becomes noticeable, but their influence is still very minor.

As the periods rise, the impact of CO_2's internal disturbances on the variability of CO_2 emissions reduces, but the impacts of disturbances in ENERGY, FDI, and TO increase. This suggests that the influence of these factors on the uncertainty of CO_2 emissions forecasts becomes stronger over time.

This statement suggests that the fluctuations in CO2 emissions are primarily caused by internal variables in the immediate future, but over a longer period, external influences begin to have an impact.

4.8. Findings

1. Relationship Between CO_2 Emissions and FDI: The investigation revealed a complex connection between FDI and CO_2 emissions. FDI initially seemed to be associated with increased CO_2 emissions, most likely as a result of the growth of energy-intensive sectors. However, FDI eventually improves environmental circumstances as the economy expands and matures, maybe due to the adoption of greener practices and technology. This result is consistent with research that indicates FDI has two effects on environmental quality, depending on the kind of FDI and the stage of economic growth.
2. Trade Openness and CO_2 Emissions: It was discovered that there is a tight link between trade openness and CO_2 emissions. Due to the scale impact of economic growth and industrialization, trade openness is linked to higher CO_2 emissions; yet, it also has the potential to lower emissions by adopting greener practices and technology imported from more developed nations. According to your results, trade sectors, the environmental standards of trading partners, and the Ivory Coast's regulatory structure all impact the net effect of trade openness on CO_2 emissions in that nation.
3. The Role of Energy Consumption: The association between FDI, economic openness, and CO_2 emissions was shown to be significantly mediated by energy usage. The total effect of these economic activities on CO_2 emissions is predominantly determined by the kind of energy sources (renewable vs. non-renewable). Increased CO_2 emissions correlate with increased energy use, especially non-renewable sources. This emphasizes how crucial it is to switch to greener energy sources to lessen the negative effects of economic growth on the environment.
4. Policy Implications: The results show that Ivory Coast needs strong environmental laws and regulations to control the environmental effects of FDI and trade openness. Without sacrificing environmental quality, policies that support the use of renewable energy, cleaner technology, and sustainable industrial practices can assist harness trade liberalization and foreign direct investment (FDI) for economic growth.

5. Discussion

The study highlights the challenge of achieving equilibrium between environmental conservation and economic progress. It underscores the pivotal role of policy adjustments in shaping the impact of FDI and trade liberalization on CO_2 discharges. Specifically, the findings suggest that escalating environmental degradation could surpass the benefits of economic openness and FDI in the absence of adequate environmental regulations and policies.

Furthermore, by highlighting the possibility for poor nations like Ivory Coast to pursue economic growth ecologically sustainably, the study adds to the larger conversation on sustainable development. It necessitates a sophisticated comprehension of the circumstances in which trade liberalization and foreign direct investment may support both environmental sustainability and economic growth.

This thesis offers an extensive analysis that contributes to the body of knowledge already available on the topic and offers useful advice to decision-makers in Ivory Coast and other comparable situations who want to maximize the positive effects of globalization while reducing its negative effects on the environment.

6. Conclusion, Recommendations, Limitations

In the context of Ivory Coast, a developing country at a pivotal point in its economic development and environmental sustainability, this thesis thoroughly investigated the complex relationships between trade openness, energy consumption, and CO_2 emissions. This work has shed light on the intricate dynamics that underlie these interactions through rigorous econometric analysis using the ARDL model.

The results highlight the important short-term effects of current energy consumption and FDI changes that lag on CO_2 emissions, highlighting the delicate balance that Ivory Coast has to maintain between harnessing economic globalization for growth and reducing its environmental impact. The research indicates that although FDI and trade liberalization can stimulate economic growth, their impact on carbon emissions mostly depends on the nature of energy usage and the efficiency of environmental laws.

Furthermore, a statistically significant error correction term implies that long-term equilibrium deviations are systematically corrected, suggesting that the Ivorian economy can adjust and adapt to external shocks in a way that may eventually be consistent with environmentally sustainable practices.

This thesis adds empirical support for the necessity for careful policy interventions to the growing knowledge on sustainable development in developing economies. With a deliberate push toward renewable energy sources and the adoption of cleaner technology, these policies must seek to draw in environmentally friendly investment from foreign countries and encourage trade openness in less carbon-intensive sectors.

In conclusion, like many developing countries, Ivory Coast faces both possibilities and obstacles in its path to

sustainable development. The conclusions drawn from this research support a comprehensive strategy that combines environmental sustainability with economic prosperity. It makes the case for forming alliances between international investors, policymakers, and the general public to promote green investments, capitalize on free trade, and ultimately lead Ivory Coast toward sustainable development that preserves its natural heritage without sacrificing it for financial gain.

While providing insight into the unique circumstances of Ivory Coast, this research also provides a model for comparable investigations in other emerging nations juggling the competing demands of environmental sustainability and economic development.

6.1. Policy Recommendations

1. Promote Green FDI: Encourage foreign direct investments that are consistent with sustainable environmental practices. Encourage industries that reduce the carbon footprint of industrial expansion in Ivory Coast by using clean technology and eco-friendly practices.
2. Improve Trade Regulations: Enhance trade rules to encourage importing ecologically friendly products and green technology. Put tariffs and non-tariff obstacles in place to deter the entry of goods and services with high carbon emissions.
3. Strengthen Environmental Regulations: Create and implement strict environmental laws that drive domestic and international businesses to switch to more environmentally friendly manufacturing practices. This involves encouraging renewable energy sources, establishing emissions limits, and providing financial support for carbon capture projects.
4. Invest in Renewable Energy: To lessen reliance on fossil fuels, significantly boost investments in the infrastructure supporting renewable energy sources. This includes funding for hydroelectric, solar, and wind power projects from the governmental and commercial sectors.
5. Educate and Empower: Start educational initiatives to inform the public and business communities about the value of environmental sustainability and the part that trade and investment play in attaining it.
6. International Cooperation: Work with foreign partners to get financing for sustainable initiatives and green technology. Engage in active participation in international environmental accords and projects.
7. Monitor and Evaluate: Put in place a reliable method to monitor how trade and FDI affect the environment. Utilize this information to evaluate and improve policies regularly to make sure they properly support sustainable development.

6.2. Study Limitations

1. Data Accessibility and Quality: The study was limited by the accessibility and caliber of data on Ivory Coast's energy use, trade openness, CO_2 emissions, and foreign direct investment. More thorough and frequent data might help future research better understand the subtleties of these interactions.
2. Temporal Scope: Data up to 2021 served as the basis for the study's conclusions. The associations found may alter if environmental and economic policies change. It needs ongoing observation and study to comprehend these processes across time.
3. Generalization: Although the study offers insightful information for Ivory Coast, its conclusions might not be immediately transferable to other nations because of variations in their energy mixes, economic structures, and environmental regulations. Comparative research encompassing several nations may be able to reveal both nation-al quirks and general patterns.
4. Methodological Restrictions: ARDL and VECM were the main tools used to analyze this work. Even if these approaches are reliable, investigating other econometric strategies may provide more light on the intricate linkage that exist between FDI, trade openness, energy use, and CO_2 emissions.
5. Emphasis on CO_2 Emissions: As a stand-in for environmental deterioration, CO_2 emissions were the study's primary emphasis. For a more comprehensive evaluation of the environmental effect, future studies might consider a wider variety of environmental indicators, such as water use, rates of deforestation, and biodiversity loss.

Future studies that address these constraints may offer an even more profound understanding of how to manage FDI and trade openness sustainably in the face of environmental issues on a global scale.

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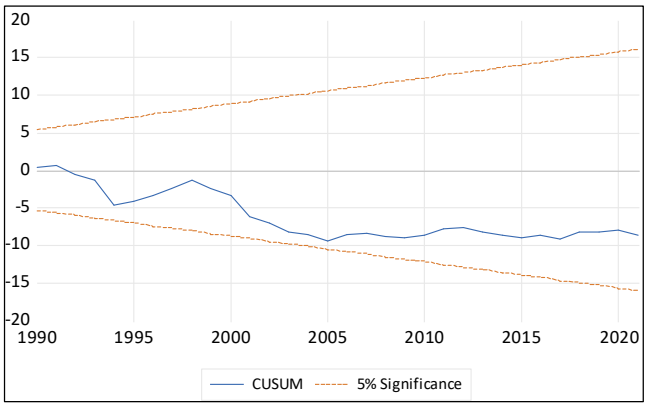
Appendixes

Appendix 1: Diagnostics Test Table

Tests	F-statistics	Prob**
Breusch-Godfrey Serial Correlation LM Test	1.3019	0.2869
Jarque-Bera	1.8769	0.3912
Heteroskedascity Test: ARCH	0.8853	0.3529

Appendix 2: Cusum Test



Cusum Test

Appendix 3: Ramsey Reset Test

Test	Value	Degrees of Freedom (df)	Probability
t-statistic	0.9621	31	0.3434
F-statistic	0.9256	(1, 31)	0.3434
Likelihood ratio	1.17689	1	0.2780

Appendix 4: Variance Decomposition

Period	S.E.	CO_2	ENERGY	FDI	TO
1	0.0888	100.0000	0.0000	0.0000	0.0000
2	0.1025	98.1856	1.4099	0.3060	0.0985
3	0.1098	92.7724	2.5197	0.5530	4.1548
4	0.1144	86.8989	2.9866	0.7282	9.3864
5	0.1179	82.0108	3.2110	0.8873	13.8910
6	0.1203	78.7060	3.2929	1.0598	16.9413
7	0.1220	76.7124	3.3123	1.2300	18.7452
8	0.1231	75.5756	3.3077	1.4075	19.7092
9	0.1238	74.9307	3.2965	1.5861	20.1866
10	0.1242	74.5405	3.2848	1.7695	20.4058