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Exploring the Linkage between Financial Development and Ecological Footprint in Egypt: Evidence from AVECM Analysis

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ABSTRACT

This study examines the dynamic relationship between financial development and environmental sustainability in Egypt using a Vector Error Correction Model (VECM) and Granger causality tests. The research focuses on key indicators of financial development, namely Domestic Credit to the Private Sector (DCPS) and Foreign Direct Investment (FDI), and their impact on CO2 emissions. The VECM results highlight a long-term equilibrium relationship, where both FDI and DCPS have significant impacts on CO2 emissions, reflecting the environmental implications of financial growth. Specifically, FDI is associated with increased environmental degradation, while the effect of DCPS is positive but less pronounced. The Granger causality test reveals a bidirectional causal relationship between DCPS and CO2 emissions, indicating interdependence between financial development and environmental degradation. Furthermore, there is evidence of unidirectional causality from CO2 emissions to FDI, suggesting that environmental conditions may influence foreign investment decisions. These findings underscore the importance of implementing sustainable financial policies to mitigate the environmental impact of financial development in Egypt.

Keywords: Financial Development, CO2 Emissions, Ecological Footprint, VECM, Granger Causality Test
JEL Classifications: Q01; Q50; Q51; D51

1. INTRODUCTION

The relationship between sustained economic growth and environmental sustainability remains a highly debated topic in environmental economics. Advocates of a pessimistic viewpoint argue that continuous growth fundamentally conflicts with environmental sustainability. They assert that economic expansion depends on the extensive use of natural resources for energy and raw materials, as well as on the environment's capacity to absorb waste, leading to substantial environmental degradation. From this perspective, achieving environmental sustainability is only possible by halting economic growth (Daly, 2015).

In contrast, others hold a more optimistic view, suggesting that economic growth can be compatible with environmental sustainability through continuous technological advancements. This perspective emphasizes the importance of adopting green technologies and alternative production methods, along with sustainable consumption practices, which can support economic growth in the medium to long term (Grossman and Krueger, 1995; Panayotou, 1993; Alagidede et al., 2016).

Climate change is a pressing issue of our time. According to the Intergovernmental Panel on Climate Change (IPCC), the expected changes in the climate will cause significant shifts in ecosystems, which will, in turn, impact development and global well-being (Elsayed, 2023). Greenhouse gas emissions, especially carbon dioxide, are central to this problem. The increasing levels of these gases in the atmosphere are a major driver of climate change and its effects (Yudaruddin et al., 2023).

Energy is essential for the production of most goods and services and is pivotal for driving economic growth (Lu, 2017; Ma and Fu, 2020). However, the rapid rise in energy consumption is closely associated with a significant increase in greenhouse gas emissions (Rehman and Rashid, 2017; Li et al., 2023; Muhammad, 2019; Zhang et al., 2019). Consequently, it is crucial to analyze the factors influencing energy consumption to guide policymakers in balancing economic growth with environmental protection. These factors encompass trade openness, urbanization, industrialization, and energy consumption itself. Recently, the role of financial development as a macroeconomic factor has gained attention for its potential impact on energy consumption levels and, by extension, emissions. Researchers have noted that overlooking the financial dimension could result in misleading empirical findings (Shahbaz et al., 2013; Tamazian et al., 2009).

Given that financial development is a pivotal factor influencing both energy consumption and carbon emissions—each of which significantly affects the other—the relationship among financial development, economic growth, and carbon emissions has become a prominent topic in global energy-related economic research (Li and Wei, 2021; Acheampong et al., 2020; Manta et al., 2020; Huang and Guo, 2023; Dong et al., 2024). The role of financial development in economic growth and its subsequent impact on environmental quality is vital, as it hinges on the availability and efficient utilization of financial resources, which are intrinsically linked to economic expansion (Khan et al., 2019). This focus has led numerous economic studies to consider financial development as a key variable in exploring the interplay between growth and environmental outcomes (Omri et al., 2015; Shahbaz et al., 2016; Jalil and Feridun, 2011; Shahzadi et al., 2023).

The concept of financial development broadly encompasses the expansion and enhancement of the efficiency of domestic financial sectors (Ma and Fu, 2020). Its significance in driving economic growth has attracted considerable attention from policymakers and researchers, especially following the global financial crisis. While financial development is crucial for boosting economic growth and fostering technological advancement, it is also recognized for its substantial impact on environmental quality, particularly regarding carbon emissions (Acheampong, 2019; Abid, 2017; Tamazian et al., 2009).

Scholars have presented differing views on the impact of financial development on carbon emissions. The first perspective suggests that financial development may contribute to reducing carbon emissions, as it is believed that companies need to upgrade production technologies and enhance market competitiveness, which requires sufficient financial support to lower production costs (Dasgupta et al., 2001; Islam et al., 2013; Yuxiang and Chen, 2011). Additionally, in response to environmental degradation, governments often initiate various eco-friendly projects and promote industrial shifts towards the use of clean energy. Based on the implemented policies, financial institutions can provide the necessary funding to support these projects or programs, contributing to the improvement of energy infrastructure and the reduction of emissions (Jiang and Ma, 2019).

Enterprises listed on the stock market are generally prominent companies that exert significant influence on the national economy. Due to stock exchange requirements, these companies are obliged to regularly disclose information and are subject to stringent oversight by financial authorities and the public. This compels them to cultivate a positive image by taking on social responsibilities, such as environmental protection, through the adoption of eco-friendly technologies, which may help reduce carbon emissions. These effects can be considered the ‘negative consequences’ of financial development on carbon emissions) Islam et al., 2013; Tamazian et al., 2009; Dasgupta et al, 2001; Jiang and Ma, 2019).

The alternative view (the positive impact) argues that financial development can contribute to higher emissions. Sadorsky (2010) and Dogan & Turkekul (2016) suggest that an efficient financial system broadens access to funding, allowing firms to secure capital at lower costs. This enables companies to expand production by building new facilities, acquiring more equipment, and increasing hiring, all of which lead to higher carbon emissions. Likewise, financial development can improve consumer services, encouraging individuals to make larger purchases, such as homes, cars, and appliances. This, in turn, drives up overall consumption and results in a significant rise in carbon emissions (Ang, 2008; Sadorsky, 2010; 2011; Shahbaz and Lean, 2013b; Çoban and Topcu, 2013)

In Egypt, the energy sector is a crucial pillar of development, contributing approximately 13% to the GDP)Ibrahiem, 2020). This sector is vital for meeting the energy needs across all economic activities. Consequently, economic growth in Egypt is closely tied to the stability and availability of energy supplies. For sustainable development to be realized, it is essential that the energy sector aligns with environmental considerations and supports the achievement of the seventh Sustainable Development Goal, which focuses on ensuring access to clean and affordable energy (IRENA, 2018).

Given the crucial role of financial development in boosting economic growth, significant efforts towards financial liberalization in Egypt were initiated in 1991 as part of a broader economic reform program. Prior to this, financial development was heavily constrained by government intervention (Mohieldin et al., 2019).

2. LITERATURE REVIEW

Financial development is crucial for fostering economic growth as it boosts capital accumulation, enhances productivity, generates job opportunities, and improves income distribution. Numerous studies support these findings, including Pagano (1993), King and Levine (1993), Bekaert et al. (2005), Ibrahim and Alagidede (2018), Bist (2018), and Yang (2019). Despite its benefits, particularly for developing and emerging economies, financial development can negatively impact the environment if it channels capital into energy-intensive industries (Ahmad et al., 2020; Ganda, 2019).

The literature presents three alternative hypotheses regarding the link between financial development and environmental degradation, focusing on energy consumption and industrialization. The first hypothesis suggests that financial development can drive environmental degradation by increasing energy use and industrial output (Abbasi and Riaz, 2016; Acheampong, 2019). By expanding access to affordable credit, financial development allows households to purchase energy-intensive appliances and vehicles, leading to higher energy consumption. Similarly, it provides businesses with access to low-cost capital, enabling them to acquire additional machinery, equipment and even establish new factories, all of which contribute to greater energy use. Additionally, financial development fosters wealth creation through improved risk diversification, which in turn enhances consumer and business confidence, spurring economic growth and further boosting energy consumption (Acheampong, 2019; Sadorsky, 2010). Furthermore, financial development encourages industrialization, often linked to increased industrial pollution and higher levels of greenhouse gas emissions (Acheampong, 2019; Jensen, 1996; World Bank, 2000).

The second hypothesis in the literature proposes that financial development can lead to environmental improvement through growth and foreign direct investment (FDI) (Acheampong, 2019; Tamazian et al., 2009). This view suggests that financial development attracts FDI and promotes research and development (RandD), which, in turn, mitigates environmental degradation by fostering economic growth and development. With access to advanced technologies, companies may adopt more energy-efficient, clean, and eco-friendly production methods, enhancing environmental sustainability both locally and globally (Acheampong, 2019; Abbasi and Riaz, 2016). A well-developed financial sector provides low-cost capital or incentives for companies and governments to invest in environmentally sustainable projects (Dasgupta et al., 2001; Tamazian and Rao, 2010; Tamazian et al., 2009). Furthermore, financial development can improve corporate governance, encouraging firms to be more attentive to environmental concerns (Claessens and Feijen, 2007). Additionally, FDI can facilitate the transfer of green technologies from investors' home countries to host countries, supporting environmentally friendly industries and reducing CO_2 emissions (Acheampong, 2019). On the other hand, a third hypothesis argues that financial development has no direct or indirect effect on carbon emissions.

Zhang (2011) investigated the impact of financial development in China using a co-integration and causality approach, finding that financial development in China significantly contributes to increased carbon emissions. The study also revealed that the financial intermediation measure had a more substantial effect on carbon emissions than other financial development indicators. Similarly, Boutabba (2014) found that financial development has a long-term positive impact on carbon emissions in India. Maji et al. (2017) observed that financial development, expressed as domestic credit provided by banks to the private sector, increases carbon emissions from the transportation, oil, and gas sectors. Shahbaz et al. (2015) examined the effect of financial development, represented by domestic credit to the private sector, on carbon emissions in India, and found that financial development indeed boosts carbon emissions. Sehrawat et al. (2015) reached the same conclusion.

Shahbaz et al. (2016) examined the asymmetric impact of financial development on carbon emissions in Pakistan from 1985 to 2014, focusing on both banking and financial market indicators. The results indicated that both the stock market and the bank-based financial development index hinder environmental quality. Similarly, Cetin et al. (2018) studied the impact of financial development on carbon emissions in Turkey using the ARDL approach and VECM model from 1960 to 2013. The study found a positive long-term relationship between financial development and carbon emissions.

Al-Mulali et al. (2015a) employed cointegration testing and FMOLS to investigate the impact of financial development on carbon emissions across 129 countries. They found that financial development, as measured by domestic credit to the private sector, increases carbon emissions. Similarly, using the GMM system, Hao et al. (2016) discovered that financial depth, indicated by the ratio of loans and deposits to GDP, contributes to higher carbon emissions in 29 Chinese provinces. Their results also revealed a U-shaped relationship between financial development and carbon emissions. Additionally, Acheampong et al. (2019) examined both the direct and indirect effects of financial development on carbon emissions in 46 sub-Saharan African countries over the period from 2000 to 2015, utilizing various financial development indicators. The study found that the impact of financial development on carbon emissions varies depending on the indicator used. For instance, the research indicated that broad money supply and domestic credit to the private sector from banks increase carbon emissions, whereas foreign direct investment, liquid liabilities, and domestic credit to the private sector from the financial sector have minimal effects on carbon emissions.

In their study, Ehigiamusoe and lean (2019) employed FMOLS and DOLS models to examine the impact of financial development on carbon emissions across 122 countries from 1990 to 2014. They discovered that financial development led to a reduction in carbon emissions in high-income countries, while it increased emissions in low- and middle-income countries. Bui (2020) analyzed a global sample of 100 countries from 1990 to 2012 and found that financial development has a direct positive impact on environmental degradation. Similarly, Tamazian and Bhaskara Rao (2010) argue that financial liberalization may be detrimental to environmental quality, particularly in transitioning economies lacking strong institutions. In a study by Yang et al. (2023), which analyzed data from 283 Chinese cities between 2006 and 2019, it was discovered that financial development—measured by financial institution loans as a percentage of GDP—and industrial upgrading had a significant positive impact on carbon emissions.

Study by Yudaruddin et al. (2023), which analyzed the impact of financial development on greenhouse gas emissions in Indonesia from 2000 to 2019, it was found that there is a significant and positive relationship between financial development and total greenhouse gas emissions.

(Dong et al., 2024) conducted the static and dynamic relationships among financial development, carbon dioxide emissions, and sustainable development across 30 Chinese provinces from 2005 to 2021. Using the entropy weight method, fixed effect model, and panel vector autoregressive (PVAR) model, the research found that financial development contributes positively to sustainable development, while carbon dioxide emissions have a significant negative impact. The PVAR model further revealed that the effects of financial development and carbon dioxide emissions on sustainable development differ over time, highlighting the need for government interventions tailored to various stages to promote sustainable development.

Conversely, numerous empirical studies have shown a significant positive correlation between energy consumption and carbon emissions, indicating that energy consumption is a crucial factor contributing to environmental degradation (Rehman and Rashid, 2017; Zhang et al., 2019). In this context, many studies have suggested that financial development can lead to increased energy consumption. A more developed financial system can provide funds to enterprises at lower costs, facilitating the expansion of production and subsequently increasing energy consumption. Additionally, financial development enhances consumers' access to credit, which significantly encourages higher purchases of goods, including automobiles and electrical appliances, thus driving up energy demand (Ma and Fu, 2020; Sadorsky, 2010; Ozturk and Acaravci, 2013; Ahmed, 2017; Mukhtarov et al., 2018).

On the other hand, Dogan and Turkekul (2016) argue that financial development can lead to increased carbon emissions. They suggest that an efficient financial system can expand funding channels, allowing companies to access capital at significantly lower costs. This facilitates production expansion, which results in a substantial increase in carbon emissions. Additionally, financial sector development can improve consumer services, making it easier for individuals to manage their consumption over time and encouraging them to purchase more goods, such as real estate, vehicles, and other electrical appliances.

(Habiba et al., 2023) investigate the impact of financial development, renewable energy consumption, and green technology on carbon emissions in seven emerging countries between 1990 and 2020. Using various econometric techniques, the findings revealed that financial development increases carbon emissions, while renewable energy and green technology reduce them in the long run. Additionally, financial development, when combined with renewable energy, is less harmful to the environment and improves environmental quality through the green technology channel. The study recommends promoting green technology and renewable energy to achieve sustainable development goals.

Turning to an alternative perspective, Tamazian et al. (2009) investigated the impact of financial development on carbon emissions in BRICS countries using a random-effect model. Their results indicated that financial development—measured by market capitalization, foreign direct investment, the ratio of deposit bank assets to GDP, capital account convertibility, financial liberalization, and financial openness—reduces carbon emissions. Extending their previous study, Rao et al. (2010) employed both the random-effect model and GMM to examine the effect of financial development on carbon emissions in 24 transitional economies, finding that financial liberalization enhances environmental quality.

Hao et al. (2016) utilized the GMM system to analyze the effects of financial development on carbon emissions in 29 Chinese provinces and discovered that financial efficiency, indicated by the loan-to-deposit ratio, mitigates carbon emissions. Additionally, Shahbaz et al. (2013b) found that financial development, represented by domestic credit to the private sector, contributes to a reduction in carbon emissions. Shahbaz et al. (2018) used the bootstrapping bound testing approach to assess the impact of financial development, foreign direct investment, and energy innovation on carbon emissions in France, confirming that financial development has a negative effect on carbon emissions. Jalil and Feridun (2011) employed the ARDL model to examine the impact of financial development on carbon emissions in China. Their results revealed that financial development—measured by liquid liabilities and the ratio of private sector credit to GDP—leads to a reduction in carbon emissions. Similarly, Nasreen et al. (2017), using the ARDL methodology, found that financial development improves environmental quality. Additionally, Yuxiang and Chen (2011) discovered that financial development, as indicated by ratios of banking credit to GDP, private sector credit to GDP, and non-private sector credit to GDP, lowers carbon emission intensity. Xing et al. (2017) reached a similar conclusion.

Using the ARDL approach, Maji et al. (2017) found that financial development, as measured by domestic credit provided by banks and the private sector to the private sector, reduces emissions in the manufacturing and construction industries in Malaysia. Similarly, Charfeddine and Khediri (2016), using Gregory-Hansen cointegration and Granger causality tests, determined that financial development decreases carbon emissions in the short term in Turkey for the period 1960-2011.

This literature review provides a comprehensive overview of the impacts of financial development on carbon emissions, highlighting the diverse findings from previous studies. While some research supports the notion that financial development may reduce emissions, other studies reveal its potential role in increasing environmental pollution. The varying results indicate that the effects of financial development may depend on the financial indicators used, the nature of the studied economy, and different dimensions such as local financial sector development or financial depth. Although numerous studies have examined the relationship between financial development and carbon emissions in various countries, such as Bangladesh, Brazil, India, Greece, Indonesia, Iran, China, Pakistan, Portugal, turkey and USA there is a scarcity of research exploring this relationship in Egypt. This variation underscores the need for more detailed investigations to improve our understanding of how financial development can be managed to contribute to environmental sustainability in Egypt.

3. DATA AND METHODOLOGY

3.1. Data Description

This study draws on data from the World Bank Development Indicators to examine the long-term and causal relationships between carbon dioxide emissions per capita, financial development, in Egypt over the period 1990 to 2023. Carbon dioxide emissions are measured in metric tons per capita, while financial development is proxied by domestic credit to the private sector and foreign direct investment (FDI). Additionally, trade openness, the annual growth rate of GDP per capita, and the industrial value-added as a percentage of GDP are considered key explanatory variables. The descriptive statistics for all the variables used in this analysis are presented in Table 1. So, the study focuses on these variables by considering the linear equation (1):

$$CO_2=\beta_0+\beta_1 DCPS_t+\beta_2 FDI_t+\beta_3 TO_t+\beta_4 GDPpc_t+\beta_5 IND_t+\epsilon_t \quad (1)$$

3.2. Variance Inflation Vector Test

The Variance Inflation Factor (VIF) test is a statistical tool used to identify multicollinearity among independent variables in regression analysis. Multicollinearity can inflate standard errors and lead to unreliable coefficient estimates. A VIF of 1 indicates no correlation, while values between 1 and 5 suggest moderate correlation, and values above 5 (or 10) indicate significant multicollinearity that may require corrective measures (Alin, 2010), Table 2 illustrates that all VIF values remain below 10, indicating no multicollinearity.

4. RESULTS AND DISCUSSION

To examine the relationship between financial development and carbon emissions, we employ econometric techniques to analyze time series data. The methodology follows several key steps. First, we test the variables for stationarity and determine their cointegration order, ensuring the time series share the same order, as indicated in equation (2). Next, we examine the potential long-term relationship between financial development and carbon emissions by employing the Johansen cointegration test. If a long-term association is established, and the time series are stationary at the first difference I(1), we apply a Vector Error Correction (VECM) model. Should cointegration be confirmed, the residuals from the equilibrium regression are used to estimate an error correction model. To explore causal linkages between financial development and carbon emissions, we conducted the Granger Causality Test. Finally, we perform diagnostic tests to assess the model's validity, including tests for heteroscedasticity, serial correlation, normality, and stability.

4.1. Unit Root Test

To investigate long-term relationships among variables, Johansen and Juselius (1990) assert that such analysis is contingent upon meeting the conditions of stationarity for the time series. Specifically, if two series are co-integrated of order d (denoted as I(d)), each must be differenced d times to achieve stationarity. For instance, when d=0, the series are stationary at levels, while for d=1, first differencing is necessary to attain stationarity. A time series is deemed non-stationary if its mean, variance, and auto-covariance are not constant over time (Johansen and Juselius, 1990). Transforming non-stationary variables into a stationary process is crucial, as failure to do so may hinder their convergence toward a long-term equilibrium. Stationarity can be assessed using two primary approaches: the Augmented Dickey-Fuller (ADF) test (1979) and the Phillips-Perron (PP) test (1988). These methods are known as unit-root tests because they examine the presence of unit roots within the series. The equation for the ADF test is presented below:

The equation for the Augmented Dickey-Fuller (ADF) test is expressed in equation (2):

$$\Delta Y_t=\beta_1+\beta_{2t}+aY_{t-1}+\delta_3\sum\Delta Y_{t-1}+\epsilon_t \quad (2)$$

In this equation ϵ_t represents the error term, β_1 is the drift term, β_2 denotes the time trend, and Δ is the differencing operator. The ADF test evaluates whether a=0, which leads to the formulation of the null and alternative hypotheses for the unit root tests as follows:

Null hypothesis (H0): a =0 (indicating that Y_t is non-stationary or has a unit root).

Alternative hypothesis (H1: a <0 (indicating that Y_t is stationary or does not possess a unit root).

The null hypothesis can be rejected if the calculated t-value (ADF statistic) falls to the left of the corresponding critical value. If a <0is established, it indicates that the variable in question is stationary. Conversely, if the null hypothesis a=0 cannot be rejected, it suggests that the variables represent non-stationary time series and exhibit unit roots in their levels. Typically, however, after taking the first differences, the variable will become stationary (Johansen and Juselius, 1990). In contrast, the specification of the Phillips-Perron (PP) test is similar to that of the ADF test; however, the PP test employs a nonparametric statistical method

Table 1: Descriptive statistics

Variables	Co2	DCPS	FDI	TO	GDPpc	IND
Variables. description	CO2 emissions (metric tons per capita)	Domestic credit to private sector (% of GDP)	Foreign direct investment, net inflows (% of GDP)	Trade (% of GDP)	GDP per capita growth (annual %)	Industry (including construction), value added (% of GDP)
Mean	1.935944	35.75353	2.300677	46.76547	2.271852	46.76547
Median	1.961123	31.94437	1.516940	44.49694	2.180962	44.49694
Maximum	2.402416	54.93114	9.348567	71.68063	5.078168	71.68063
Minimum	1.400233	22.05863	−0.204543	29.85697	−1.283898	29.85697
Standard deviation	0.333624	11.39031	2.188150	10.64693	1.618188	10.64693
Skewness	−0.094464	0.526303	1.983257	0.0504924	−0.131704	0.504924
Kurtosis	1.483343	1.741915	6.514640	2.424375	2.515104	2.424375
Jarque bera	3.3099253	3.811906	39.78841	1.914107	0.431386	1.914107

to address serial correlation in the error terms without introducing lagged differences (Burakov and Freidin, 2017). In this paper, both the ADF and PP tests are utilized to assess the stationarity of the sampled time series as shown in Table 3.

Following the unit root test, all variables were identified as first-order difference stationary sequences, indicating the possibility of a cointegration relationship. To explore this, the Johansen cointegration test, in conjunction with a Vector Autoregressive (VAR) analysis, was applied. Cointegration tests require selecting the appropriate lag length, which is crucial for accurate model estimation. In this study, the optimal lag length was determined using multiple statistical criteria, including the Akaike Information Criterion (AIC), Schwarz Criterion (SC), Likelihood Ratio (LR), Final Prediction Error (FPE), and Hannan-Quinn Criterion (HQ). As shown in Table 4, these criteria consistently indicate that the optimal lag length for the model is 2.

As a result, we constructed a model using a 2-year time lag to analyze the short-term relationship. The diagnostic test results for the VAR model, examining residual heteroscedasticity, autocorrelation, and stability, are shown in Table 5. Table 5 indicates that the model is stable, with no signs of heteroscedasticity or serial correlation in the residuals.

4.2. Johansen Co-integration Test

The Johansen co-integration test, developed by Johansen and Juselius (1990), is a method used to determine the existence of long-term equilibrium relationships between non-stationary time series variables. The test is based on a Vector Autoregressive (VAR) model and is specifically applicable when variables are integrated of the same order, typically I (1). The test evaluates the rank of the matrix formed by the error terms of the VAR model. If the rank is zero, there is no co-integration; if the rank is one or more, it indicates the presence of one or more co-integrating vectors. The Johansen test employs two statistics: the trace statistic and the maximum eigenvalue statistic. The trace statistic tests the null hypothesis that the number of co-integrating vectors is less than or equal to r against a general alternative, while the maximum eigenvalue statistic tests the null hypothesis of r co-integrating vectors against the alternative of r+1. The basic VAR equation for the Johansen test is expressed as:

$$\Delta Y_t = \Pi Y_{t-1} + \Sigma \Gamma_i \Delta Y_{t-i} + \varepsilon_t \quad (3)$$

Where (ΔYt) represents the differenced variables, (Π is the co-integration matrix, and (Γi) are the short-run adjustment coefficients. The test then evaluates the eigenvalues of the (Π) matrix to assess the presence of co-integration. The results of both methods are shown in Table 6:

The Johansen cointegration test results, based on both the Trace and Maximum Eigenvalue tests, confirm the presence of multiple cointegrating vectors among the variables. In the Trace test, the statistic for the null hypothesis of no cointegration (None) is 237.37, which significantly exceeds the critical value of 95.75, with a P-value of 0.0000. This indicates a rejection of the null hypothesis, suggesting at least one cointegrating relationship. At each subsequent rank (1 through 5), the trace statistics similarly exceed the critical values, with all P-values below the 0.05 threshold, providing strong evidence for the rejection of the null hypothesis in favor of multiple cointegrating vectors. The Maximum Eigenvalue test further supports these findings. The test statistic for the null hypothesis of no cointegration is 87.18, which is also greater than the critical value of 40.08, with

Table 2: VIF test

Variable	Centered VIF
c	NA
GDPPC	2.457805
TO	1.594070
IND	1.687475
DCPS	1.149029
FDI	3.508505
FDI	3.508505

Table 3: Results of unit root test

ADF test			Pp test		
Variables	Level	Probability	T−static	Prob.	T−stat
GDPpc	At level	0.0602	−3.464253	0.0634	−180.389
	First difference	0.0000***	−8010.148	0.0000***	−8315417
Co2	At level	0.9945	−00.00355	0.9796	−00.478885
	First difference	0.0310*	−30.7800.821	0.0375*	−30.6920.885
DCPS	At level	0.4293	−2280.570	0.7765	−150.868
	First difference	0.0242*	−30.2800.600	0.0236*	−30.9030.488
FDI	At level	0.0877	−330.321	0.4364	−20.2720.554
	First difference	0.0354*	−30.7180.754	0.0324*	−30.7590.936
IND	At level	0.6789	−10.8060.064	0.6287	−10.9060.220
	First difference	0.0055**	−40.5480.009	0.0000***	−60.5770.069
TO	At level	0.3058	−20.5450.636	0.6657	−10.8330.074
	First difference	0.0070**	−440.209	0.0072**	−40.4080.879

Table 4: Lag length selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−330.1339	NA	53.58289	21.00837	21.28320	21.09947
1	−161.9565	262.7773	0.014453	12.74728	14.67106*	13.38496
2	−116.0140	54.55665*	0.010021*	12.12588*	15.69861	13.31014*

Table 5: Results of unrestricted VAR model diagnostic testing

Type of test	Results	Lags	LM-statistics	P-value
VAR residual serial correlation LM test	** Denotes acceptance of null hypothesis (Ho: there is no serial correlation)	1	0.219207	0.6396**
		2	0.039648	0.8422**
		3	0.208482	0.6480**
Stability condition test	All roots lie within the circle		VAR satisfies stability condition	
Heteroscedasticity (White test)	* Denotes acceptance of null hypothesis of homoscedasticity		0.1905*	0.1579*

Table 6: Results of Johansen co-integration test

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	Prob.**
No. of CE (s)	Eigenvalue	Statistic	Critical value	
None*	0.939932	237.3710	95.75366	0.0000
At most 1*	0.785103	150.1902	69.81889	0.0000
At most 2*	0.759574	102.5247	47.85613	0.0000
At most 3*	0.671084	58.33915	29.79707	0.0000
At most 4*	0.394380	23.86864	15.49471	0.0022
At most 5*	0.235439	8.322052	3.841465	0.0039
Trace test indicates 6 cointegrating eqn (s) at the 0.05 level				
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized		Max-Eigen	0.05	Prob.**
No. of CE (s)	Eigenvalue	Statistic	Critical Value	
None*	0.939932	87.18084	40.07757	0.0000
At most 1*	0.785103	47.66548	33.87687	0.0006
At most 2*	0.759574	44.18557	27.58434	0.0002
At most 3*	0.671084	34.47051	21.13162	0.0004
At most 4*	0.394380	15.54659	14.26460	0.0312
At most 5*	0.235439	8.322052	3.841465	0.0039
Max-eigenvalue test indicates 6 cointegrating eqn (s) at the 0.05 level				

*Denotes rejection of the hypothesis at the 0.05 level

a P-value of 0.0000. Similarly, at ranks 1 through 5, the test statistics exceed the respective critical values, and the associated P-values are consistently below 0.05, leading to the rejection of the null hypothesis of no cointegration across all ranks. Therefore, we can conclude that there is a long run relationship among the variables. The next sub-section will therefore present the long run relationship for the variables.

4.3. Vector Error Correction Model (VECM)

The conventional Vector Autoregression (VAR) model typically requires that all variables be stationary to ensure reliable estimation. Generally, to remove a unit root, the series is differenced, yet doing so with cointegrated series risks excessive differencing, which can eliminate the valuable insights from the long-term relationships between variables. To address this, the cointegrated VAR model, or Vector Error Correction Model (VECM), is applied. Medvegyev et al. (2015) describes the VECM as incorporating a VAR model of order p - 1 on the differenced variables while adding an error-correction term based on the known or estimated cointegrating relationship. Within the context of financial development and emissions, this model allows the establishment of a short-term dynamic relationship while adjusting for deviations from the long-term equilibrium. This approach is particularly suited to understanding how financial variables might drive changes in emissions, correcting for both short-term fluctuations and the long-term equilibrium path. An appropriately specified VECM can be represented as follows:

$$\ddot{A}CO2_t = \gamma 11 ECT_{t-1} + \sum_{i=1}^{p-1} \varnothing_{11,i} \Delta CO2_{t-i} + \sum_{i=1}^{p-1} \varnothing_{12,i} \Delta GDPpc_{t-i} + \sum_{i=1}^{p-1} \varnothing_{13,i} \Delta DCPS_{t-i} + \sum_{i=1}^{p-1} \varnothing_{14,i} \Delta FDI_{t-i} + \sum_{i=1}^{p-1} \varnothing_{15,i} \Delta IND_{t-i} + \sum_{i=1}^{p-1} \varnothing_{16,i} \Delta TO_{t-i} + u_{1t} \quad (4)$$

$$\Delta GDPpc_t = \gamma 21 ECT_{t-1} + \sum_{i=1}^{p-1} \varnothing_{21,i} \Delta CO2_{t-i} + \sum_{i=1}^{p-1} \varnothing_{22,i} \Delta GDPpc_{t-i} + \ldots + u_{2t} \quad (5)$$

$$\Delta DCPS_t = \gamma 31 ECT_{t-1} + \sum_{i=1}^{p-1} \varnothing_{31,i} \Delta CO2_{t-i} + \sum_{i=1}^{p-1} \varnothing_{32,i} \Delta GDPpc_{t-i} + \ldots + u_{3t} \quad (6)$$

$$\Delta FDI_t = \gamma 41 ECT_{t-1} + \sum_{i=1}^{p-1} \varnothing_{41,i} \Delta CO2_{t-i} + \sum_{i=1}^{p-1} \varnothing_{42,i} \Delta GDPpc_{t-i} + \ldots + u_{4t} \quad (7)$$

$$\Delta IND_t = \gamma 51 ECT_{t-1} + \sum_{i=1}^{p-1} \varnothing_{51,i} \Delta CO2_{t-i} + \sum_{i=1}^{p-1} \varnothing_{52,i} \Delta GDPpc_{t-i} + \ldots + u_{5t} \quad (8)$$

$$\Delta TO_t = \gamma 61 ECT_{t-1} + \sum_{i=1}^{p-1} \varnothing_{61,i} \Delta CO2_{t-i} + \sum_{i=1}^{p-1} \varnothing_{62,i} \Delta GDPpc_{t-i} + \ldots + u_{6t} \quad (9)$$

So VECM integrates both long-term equilibrium (through the cointegrating relationship) and short-term adjustments (through the differenced terms and lags), making it ideal for examining cointegrated time series data. For the VEC model to produce valid results, it must meet specific conditions: the absence of serial correlation, homoscedasticity of residuals, stability, and normality. Only when these requirements are satisfied can the model's outcomes be considered reliable.

4.4. The Long Run Relationship

The long-run relationship in the Vector Error Correction Model (VECM) reveals the equilibrium association between carbon dioxide emissions (CO_2) and the explanatory financial and economic variables. Based on the estimated cointegrating coefficients, the following equation represents the long-run relationship, showing how each variable influences CO_2 emissions in equilibrium. Table 7 following table presents the normalized cointegrating coefficients from the Vector Error Correction Model (VECM) estimation

Table 7 presents the coefficients for the first normalized cointegrating equation, with standard errors shown in brackets and test statistics (t-values) in parentheses. The t-values are calculated by dividing each variable's coefficient by its corresponding standard error. From this table, it is evident that all variables are highly statistically significant. With the normalized cointegrating coefficients and their respective t-values, we can construct the long-run equation as follows:

$$CO_2=7.654+0.012241\ DCPs+0.416543\ FDI-0.203262\ IND-0.021978\ TO-0.502\ GDPpc+\varepsilon \quad (10)$$

Equation (10) above shows the estimated long run relationship that exists among the variables of interest.

The Vector Error Correction model results indicate a complex relationship between CO_2 emissions and various economic indicators. The positive and statistically significant coefficient for Foreign Direct Investment (FDI) suggests that increased FDI inflows are associated with higher CO_2 emissions, potentially due to investments in energy-intensive sectors. Similarly, the positive and significant coefficient for Domestic Credit to the Private Sector (DCPS) implies that greater credit availability may support industrial expansion, thus contributing to environmental degradation. In contrast, GDP per capita (GDPPC) exhibits a significant negative relationship with CO_2 emissions suggesting that economic growth could promote the adoption of cleaner technologies or more environmentally friendly policies. Industry value-added (IND) also shows a negative association with emissions, indicating that industrial advancements may increase efficiency or lead to greener practices. Additionally, trade openness (TO) has a significant negative effect on emissions, which could mean that more open economies gain access to cleaner technologies through trade. The constant term represents the average level of CO_2 emissions when all variables are in equilibrium, providing a baseline for emissions within this economic context.

Our next empirical analysis would therefore involve the estimation of the Vector Error Correction Model, since the just concluded cointegration test revealed the presence of long run relationship among the variables. Since both conditions have been met (all variables of interest are integrated at the same order and found to be cointegrated) this study proceeds to estimate the Vector Error Correction Model, as shown in Table 8.

The Vector Error Correction Model (VECM) results provide insights into the short-run dynamics between CO_2 emissions (D(CO_2)) and other economic variables, with the error correction term (CointEq1) indicating how quickly CO_2 emissions adjust back to long-term equilibrium after deviations. The negative and statistically significant coefficient for CointEq1 in the D(CO_2) equation (-0.007971, with a t-statistic of -2.07) suggests that CO_2 emissions correct toward equilibrium at a slow rate when external shocks occur. Analyzing the short-run relationships, the coefficient of the lagged CO_2 emissions variable, D(CO_2(-1)), is positive and significant (0.420477, t = 2.03), indicating that past CO_2 levels have a reinforcing effect on current emissions. Foreign direct investment (D(FDI(-1))) also shows a significant positive influence on CO_2 emissions (5.829747, t = 1.79), suggesting that increased FDI is associated with higher CO_2 emissions, likely due to industrial activities. Additionally, domestic credit to the private sector (D(DCPS(-1))) has a small but positive effect on CO_2 emissions (0.005178, t = 1.08), indicating that increased credit availability may facilitate economic activities that elevate emissions. The impact of GDP per capita (D(GDPPC(-1))) on CO_2 emissions is negative but not statistically significant (-0.754344, t = -3.59), implying that, in the short run, higher income levels might reduce emissions, although this relationship is not strong. Industrialization (D(IND(-1))) and trade openness (D(TO(-1))) exhibit insignificant effects on CO_2 emissions, with coefficients of 0.340828 (t = -1.92) and 0.093822 (t = 1.31), respectively. This suggests that industrial and trade activities do not significantly influence CO_2 emissions in the short term within this model.

4.5. Granger Causality Test

The Pairwise Granger Causality test evaluates the predictive relationship between two time series variables to see if one can predict changes in the other. By testing the null hypothesis, we determine if one variable Granger-causes another, implying a causal relationship where past values of one variable improve the forecast of the other (Granger, 1969) (Table 9).

The Granger causality test results for the relationship between CO_2 emissions and financial development indicators show notable interactions. Specifically, the null hypothesis that "CO_2 does not Granger cause FDI" is rejected at a 5% significance level (F-statistic = 4.95471, p-value = 0.0147), indicating that CO_2 emissions have predictive power over Foreign Direct Investment (FDI). This suggests that fluctuations in CO_2 emissions may

Table 7: Normalized Long-Run Cointegrating Coefficients from the VECM Estimation

Co2	DCPS	FDI	IND	TO	GDPpc
1	0.012241	0.416543	−0.203262	−0.021978	−0.502440
Standard Errors	(0.00439)	(0.04374)	(0.02183)	(0.00555)	(0.05678)
Test Statistics	(2.78751)	(9.52363)	(−9.30971)	(−3.96060)	(−8.84894)

Table 8: Parsimonious error correction estimates/short run dynamics

Error Correction	D (CO_2)	D (FDI)	D (DCPS)	D (GDPPC)	D (IND)	D (TO)
CointEq1	−0.007971	−1.606884	−3.371171	0.911023	1.393423	6.601716
	(−0.20702)	(−2.92132)	(−2.19277)	(1.36354)	(1.94875)	(2.84970)
D (CO_2(-1))	0.420477	5.829747	−7.085292	−0.723032	5.677678	−0.270309
	(2.03495)	(1.97199)	(−0.85877)	(−0.20165)	(1.47962)	(−0.22444)
D (FDI(-1))	0.000320	0.920777	1.355055	−0.27772	−0.433818	−0.601456
	(3.94538)	(3.28796)	(2.07559)	(0.61132)	(1.28754)	(2.32134)
D (DCPS(-1))	0.005178	0.197166	0.279646	0.030898	0.103735	0.592838
	(1.08051)	(0.28796)	(1.46132)	(0.86120)	(1.16554)	(2.05553)
D (GDPPC(-1))	0.003317	−7.54344	0.97636	−0.30377	1.490083	3.10472
	(2.25759)	(−3.59381)	(−1.66462)	(−0.12990)	(1.27102)	(0.77865)
D (IND(-1))	0.001506	−0.340829	0.34555	−0.027878	2.21924	0.75747
	(1.12180)	(−1.92904)	(−0.88878)	(1.27102)	(0.80876)	(1.92141)
C	0.006897	0.111819	0.349734	0.156747	−0.121404	−0.873470
	(0.46180)	(0.52408)	(0.58646)	(0.60482)	(−0.43772)	(−0.97234)
R-squared	0.229393	0.537949	0.379089	0.405624	0.338492	0.464045
Adj. R-squared	0.032407	0.201076	0.222170	0.240532	0.130652	0.257440

t-statistics are provided in square brackets

Table 9: Pairwise Granger Causality Tests

Null Hypothesis	Obs	F-Statistic	Prob.
DCPS does not Granger Cause CO_2	32	2.86644	0.0343
CO_2 does not Granger Cause DCPS		5.96515	0.0072
FDI does not Granger Cause CO_2	32	0.16338	0.8501
CO_2 does not Granger Cause FDI		4.95471	0.0147

influence FDI inflows, potentially due to investors response to environmental concerns or policies. Conversely, FDI does not appear to Granger cause CO_2 emissions, as indicated by the non-significant F-statistic and high p-value (0.8501), suggesting that FDI inflows do not predict changes in CO_2 emissions. For Domestic Credit to the Private Sector (DCPS), the null hypothesis that "CO_2 does not Granger cause DCPS" is also rejected (F-statistic = 5.96515, p-value = 0.0072), implying that changes in CO_2 emissions significantly influence the availability of domestic credit to the private sector. This relationship could indicate that environmental factors, reflected through CO_2 emissions, affect financial conditions within the economy. However, the null hypothesis that "DCPS does not Granger cause CO_2 emissions" is rejected at a 10% significance level (Prob. = 0.0343). This indicates bidirectional causality relationship where changes in domestic credit to the private sector (DCPS) may have predictive power over future changes in CO_2 emissions. These findings underscore the influence of CO_2 emissions on key financial development indicators, suggesting that environmental concerns might play a role in shaping financial dynamics in the long term.

4.6. Impulse Response Function Analysis

The Impulse Response Function (IRF) analysis is a common econometric tool used to assess the impact of a one-unit shock to one variable on another variable over time within a Vector Autoregressive (VAR) framework. In this context, it helps us understand how a shock in financial development indicators like Foreign Direct Investment (FDI) and Domestic Credit to the Private Sector (DCPS) might affect CO_2 emissions over a specified time horizon.

The first Figure 1a illustrates the response of CO_2 emissions to an innovation in Foreign Direct Investment (FDI). Initially, an FDI shock leads to a small negative response in CO_2 emissions, suggesting that an increase in FDI may slightly reduce emissions in the short term. However, this effect diminishes over time, with the response converging near zero, indicating that the impact of FDI shocks on CO_2 emissions is limited and potentially short-lived. According to the Granger causality test, CO_2 emissions also Granger-cause FDI, though FDI does not significantly impact CO_2 emissions. This aligns with the observed short-term negative response, as the initial reduction might reflect foreign investors' hesitation to invest in high-emission environments, yet this impact does not persist.

The second Figure 1b illustrates the impulse response of CO_2 emissions to a shock in Domestic Credit to the Private Sector (DCPS) using Cholesky decomposition. The results suggest that a positive innovation in DCPS initially leads to a slight increase in CO_2 emissions, indicating an immediate but modest effect. Over time, the response of CO_2 emissions stabilizes and continues to rise gradually, suggesting a sustained positive relationship between DCPS and CO_2 emissions. This pattern implies that an increase in credit availability to the private sector may be associated with higher emissions levels, potentially due to expanded industrial and economic activities facilitated by financial resources. However, as the forecast horizon extends, the confidence intervals (represented by dashed lines) widen, reflecting growing uncertainty in the estimates over time. These findings align with the Granger causality test results, which indicated that CO_2 emissions Granger-cause DCPS. This causality implies that changes in emissions could influence credit allocation practices, possibly as financial institutions adjust to environmental shifts or industrial demands.

4.7. Variance Decomposition Analysis

Variance Decomposition Analysis provides insights into the relative contribution of each variable's shocks in explaining the forecast error variance of other variables over time. As shown in Table 10. The Variance Decomposition Analysis of CO_2 emissions provides valuable insights into the contributions of various economic factors to fluctuations in CO_2 over time. In the initial period (Period 1), CO_2 emissions are entirely self-explanatory, with 100% of the variance attributed to CO_2 itself.

Figure 1: Results of the impulse response of carbon dioxide emissions

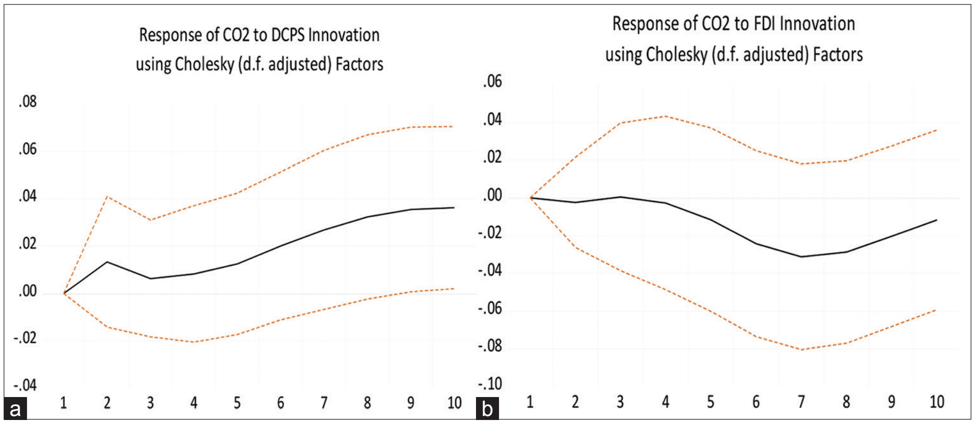


Table 10: Results of the variance decomposition of CO2 emissions

Period	S.E.	CO2	DCPS	FDI	GDPPC	IND	TO
1	0.070522	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.101095	97.20674	1.742017	0.058595	0.004179	0.898573	0.089900
3	0.117039	92.74211	1.593088	0.045364	0.140616	5.176461	0.302359
4	0.130173	84.03818	1.691707	0.082841	0.973839	12.63190	0.581539
5	0.141304	76.50580	2.219695	0.749310	1.438225	18.34350	0.743462
6	0.152044	68.34348	3.669718	3.212293	1.596119	22.16148	1.016910
7	0.162997	59.87884	5.915277	6.476947	1.623303	24.24372	1.861909
8	0.173536	52.83356	8.699007	8.453899	1.487554	25.37517	3.150813
9	0.182791	47.89761	11.61401	8.865479	1.374681	25.86988	4.378336
10	0.190645	44.59950	14.29760	8.529368	1.505772	25.71357	5.354187

As time progresses, Domestic Credit to the Private Sector (DCPS) becomes an increasingly significant contributor to the variance in CO_2, explaining around 11.29% by Period 10. This growing influence suggests that financial sector activities, represented by DCPS, may have an impact on CO_2 emissions in the longer term. Other variables such as Foreign Direct Investment (FDI), GDP per capita (GDPPC), industrial output (IND), and trade openness (TO) have relatively minor effects, each contributing less than 1.5% of the variance in CO_2 by Period 10. This decomposition highlights that while DCPS plays a notable role in explaining CO_2 variance over time, other economic variables have a limited impact, indicating that credit dynamics may have a more direct connection to environmental changes than FDI or GDP per capita in this context.

The final stage in evaluating the model involves validating its robustness and reliability. This requires conducting a series of diagnostic tests, including assessments of residual heteroscedasticity, stability, and normality. Table 11 summarizes the outcomes of these tests.

Table 11 indicates that the model adheres to essential diagnostic criteria, displaying homoscedasticity and an absence of serial, auto, and partial correlations. Figures 1-3 present further test results, specifically addressing normality and stability through the CUSUM and CUSUM square tests. The findings from Figures 1-3 confirm that the model satisfies the normality criterion.

5. DISCUSSION

This paper investigates the dynamic relationship between financial development and ecological footprint in Egypt. The analysis focuses on two key indicators of financial development: Foreign Direct Investment (FDI) and Domestic Credit to the Private Sector (DCPs). By employing a Vector Error Correction Model (VECM), the study aims to capture both the short-term and long-term impacts of these financial development indicators on Egypt's ecological footprint. This approach helps in understanding whether financial growth in Egypt contributes to environmental degradation or supports sustainable development.

The long run cointegration results as shown in table 7 indicate a dynamic relationship between financial development indicators and CO_2 emissions in Egypt. Starting with domestic credit to the private sector (DCPS), the positive coefficient suggests that an increase in domestic credit is associated with a rise in CO_2 emissions over the long term. This implies that higher financial development, as measured by credit expansion, may drive economic activities that are not environmentally sustainable. When credit availability increases, industries are likely to invest in production processes, which can lead to higher energy consumption and emissions, especially if the investments are concentrated in carbon-intensive sectors. The findings of this study are consistent with the results of studies by Al-Mulali e(2015a); Acheampong et al. (2019); Sadorsky (2010); Dogan et al. (2016); Maji et al. (2017); Shahbaz et al. (2015). But contrast with Jalil and

Table 11: Results of diagnostic testing

Test type	Value	Probability characteristic	P-value
Heteroskedasticity test: Breusch-Pagan-Godfrey			
F statistics	0.665243	Prob. F (5,28)	0.6528
Obs*R-squared	3.610120	Prob. Chi-square (5)	0.6068
Scaled explained SS	2.062097	Prob. Chi-square (5)	0.8405
Heteroskedasticity test: ARCH			
F statistics	0.075721	Prob. F (1,31)	0.7850
Obs*R-squared	0.080409	Prob. Chi-square (1)	0.7767
Breusch-Godfrey serial correlation LM test			
F-statistic	2.060066	Prob. F (4,24)	0.1178
Obs*R-squared	8.690033	Prob. Chi-square (4)	0.0693

Figure 2: Results of normality test

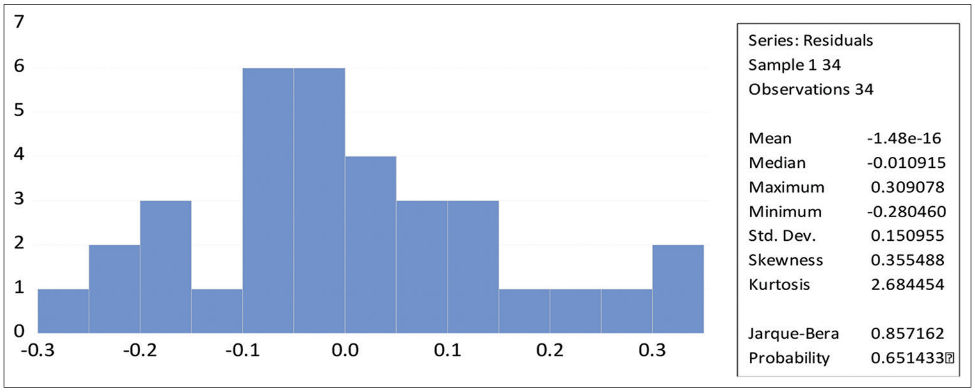


Figure 3: Results of CUSUM square test

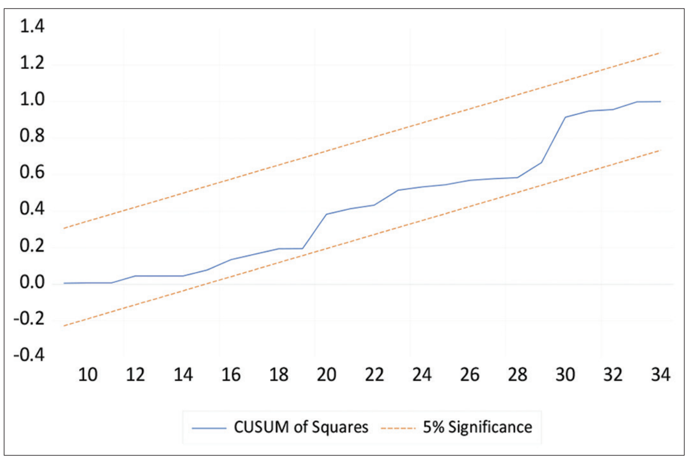
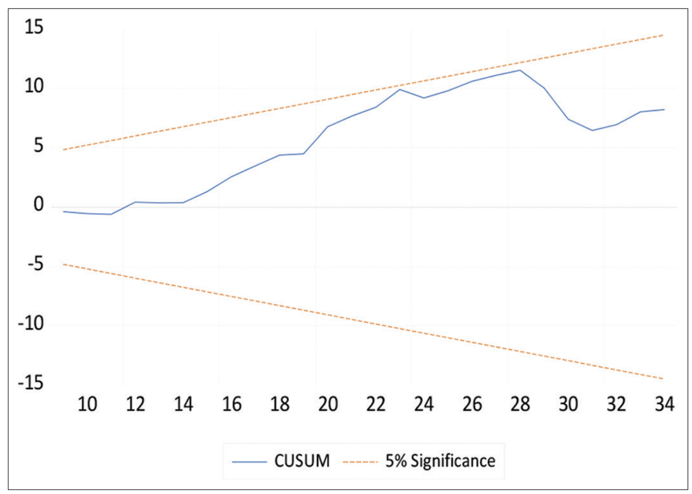


Figure 4: Results of CUSUM test



Feridun (2011); Yuxiang and Chen, 2011. which may be explained by differences in the econometric methodologies employed and the varying characteristics of the countries under investigation.

Similarly, foreign direct investment (FDI) shows a strong positive relationship with CO_2 emissions. The relatively large positive coefficient indicates that increased FDI is significantly associated with higher emissions. This result suggests that foreign investments in Egypt may be directed towards pollution-heavy industries, potentially leading to an increase in industrial activities and expansions in production that elevate the overall environmental footprint. The highly significant statistical relationship underscores the substantial impact of FDI on environmental sustainability, highlighting a potential challenge in balancing economic growth through foreign investments with environmental preservation. This result is consistent with Acheampong et al. (2019) but contrasts with the findings of Tamazian et al., 2009).

In contrast, industrialization (IND) exhibits a negative coefficient, indicating an inverse relationship between the industrial sector's contribution to GDP and CO_2 emissions. This result suggests that an increase in industrial activities does not necessarily lead to higher emissions. This result contrasts with (Abbasi and Riaz, 2016; Acheampong, 2019). this finding could be explained by the adoption of cleaner technologies or efficiency improvements in the industrial sector, or a shift towards less carbon-intensive industries (like electronics or pharmaceuticals), which have a lower impact on CO_2 emissions. This transition would result in reduced overall emissions even as industrial activity increases.

Moreover, trade openness (TO) is also negatively associated with CO_2 emissions, as indicated by the negative coefficient. This suggests that greater trade openness may contribute to reducing emissions, potentially due to the import of cleaner technologies or greener products that lower domestic pollution levels. It could also imply that trade policies are favoring industries with lower carbon footprints. The significant relationship highlights the potential role of increased trade in promoting environmental sustainability, as it may provide access to environmentally friendly technologies and encourage the adoption of greener practices.

GDP per capita (GDPpc) demonstrates a negative coefficient, indicating that higher GDP per capita is associated with lower CO_2 emissions in the long run. This finding aligns with the Environmental Kuznets Curve (EKC) hypothesis, which posits that economic growth initially leads to environmental degradation, but beyond a certain income level, the trend reverses as higher income levels foster increased environmental awareness and the adoption of cleaner technologies. The significant negative relationship suggests that as Egypt's economy grows, there may be a shift towards more sustainable practices, reducing the carbon intensity of economic activities.

The short-run dynamics of the Vector Error Correction Model as shown in Table 8 indicate that the error correction term's coefficients are statistically significant for D(DCPS) (domestic credit to the private sector) and D(TO) (trade openness), indicating that these sectors respond more actively to deviations from long-run equilibrium. The significance of the adjustment in domestic credit and trade openness may reflect that financial markets and trade policies are more responsive to environmental disequilibria in the short run. This sensitivity might be due to regulatory adjustments, investor reactions, or shifts in trade policies influenced by environmental considerations, particularly as countries focus on sustainable development goals.

Foreign direct investment (FDI) also plays a substantial role in influencing CO_2 emissions increases in FDI are associated with a rise in emissions in the short run. This may be due to capital-intensive, energy-demanding projects that typically accompany foreign investments, especially in sectors like manufacturing, energy production, and construction, which are known to have high carbon footprints. Thus, FDI appears to contribute directly to the short-term increase in emissions, suggesting that while FDI promotes economic growth, it may also bring environmental trade-offs.

Domestic credit to the private sector exhibits a positive, though statistically modest, influence on CO_2 emissions in the short run. This relationship suggests that greater credit availability may stimulate consumption and investment, which could, in turn, boost production levels and lead to higher emissions. Although the effect is not highly pronounced, this trend indicates that dynamics within the financial sector can indirectly shape environmental outcomes by facilitating more resource-intensive economic activities.

Gross domestic product per capita has a considerable effect on CO_2 emissions, showing a significant positive relationship in the short run. This implies that as economic output per person rises, emissions tend to increase as well. Higher income levels, associated with economic growth, often drive greater consumption and industrial activity, leading to heightened energy demand. Consequently, this increase in energy usage, especially in economies heavily reliant on fossil fuels, translates into higher emissions. This relationship highlights the environmental challenges tied to economic expansion, reinforcing the Environmental Kuznets Curve (EKC) hypothesis, which suggests that emissions initially rise with economic growth before potentially declining as economies reach higher development levels and adopt cleaner technologies.

The industrialization variable demonstrates a positive but statistically weak influence on CO_2 emissions, indicating that while industrial activities may contribute to emissions, their immediate impact in the short run appears limited. This could imply that other economic sectors, such as transportation or urban development, might have a more prominent role in driving emissions in the short term.

Finally, the results from the Pairwise Granger Causality Tests as shown in Table 9 provide insights into the between CO_2 emissions, domestic credit to the private sector (DCPS), and foreign direct investment (FDI) in the short run. First, the test reveals that DCPS Granger-cause CO_2 emissions, CO_2 emissions do Granger-cause DCPS. bidirectional causality suggests that past values of CO_2 emissions have predictive power over changes in domestic credit allocation to the private sector and vice versa. Economically, this could imply that higher levels of CO_2 emissions may signal environmental or regulatory concerns that influence financial sector behaviors, potentially driving credit availability toward industries that can mitigate or adapt to environmental impacts. Similarly, the Granger causality test between CO_2 emissions and FDI indicates that CO_2 emissions Granger-cause FDI, but not the reverse. This suggests that fluctuations in CO_2 emissions have predictive power over changes in FDI inflows. From an economic perspective, rising CO_2 emissions may affect the investment climate by signaling environmental challenges or regulatory shifts that could influence investor behavior, especially in sectors sensitive to environmental policies. This finding aligns with the notion that environmental considerations increasingly influence international investment decisions, as investors and policymakers seek to balance economic growth with sustainable development goals.

6. CONCLUSION AND POLICY IMPLICATION

This study investigates the long-run and short-run dynamics between carbon dioxide (CO_2) emissions and a set of key financial and economic indicators: domestic credit to the private sector (DCPS), foreign direct investment (FDI), industrial output (IND), trade openness (TO), and per capita GDP (GDPpc). Using a Vector Error Correction Model (VECM) and Granger causality tests, the analysis reveals several critical insights into the relationship between these variables and CO_2 emissions.

The long-run results indicate that DCPS and FDI have a positive and significant impact on CO_2 emissions, suggesting that financial development and increased foreign investment may contribute to higher environmental degradation. This relationship could be attributed to the increased access to capital, which often leads to higher production activities and, consequently, greater emissions. Conversely, industrial output (IND), trade openness (TO), and GDP per capita (GDPpc) exhibit negative coefficients, highlighting their potential roles in reducing emissions. The negative impact of industrial output could be explained by the adoption of cleaner technologies and improved efficiency in industrial processes, while trade openness might facilitate the transfer of environmentally friendly technologies and practices. Additionally, the negative relationship between GDP per capita and CO_2 emissions could reflect the environmental Kuznets curve (EKC) hypothesis, where higher income levels lead to increased environmental awareness and more stringent environmental regulations.

The Granger causality test results reveal bidirectional causality between DCPS and CO_2 emissions, indicating a feedback relationship where financial development and CO_2 emissions influence each other. Similarly, there is unidirectional causality from CO_2 emissions to FDI, suggesting that environmental degradation may play a role in attracting foreign investment, potentially due to lower environmental standards or "pollution haven" effects.

The findings of this study emphasize the need for a balanced approach to financial and economic development that also considers environmental sustainability. The positive long-run relationship between domestic credit to the private sector (DCPS) and CO_2 emissions suggests that financial development can drive economic growth but may also increase environmental degradation if left unchecked. Therefore, policymakers should consider integrating green financing practices, encouraging banks and financial institutions to support investments in environmentally sustainable projects, such as renewable energy and energy efficiency improvements. Furthermore, the positive association between foreign direct investment (FDI) and CO_2 emissions indicates that while FDI is a critical driver of economic growth, it may contribute to environmental challenges, particularly if foreign investors are drawn to countries with lax environmental regulations. To address this, governments should design investment policies that attract green FDI by offering incentives for projects that use cleaner technologies and comply with strict environmental standards. On the other hand, the negative coefficients observed for industrial output, trade openness, and GDP per capita suggest potential pathways for reducing emissions. Industrial efficiency improvements, through the adoption of cleaner technologies and practices, could be promoted to minimize the carbon footprint of the industrial sector. Additionally, trade policies that facilitate the exchange of green technologies and environmentally sustainable products can help mitigate emissions, leveraging the benefits of globalization while protecting the environment. Finally, as economies grow and income levels rise, there is an opportunity to implement stricter environmental regulations that reduce emissions, aligning with the Environmental Kuznets Curve hypothesis. This underscores the importance of a comprehensive policy framework that supports economic growth while prioritizing environmental protection, ultimately contributing to sustainable development goals.

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