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Exploring industrialization and environmental sustainability dynamics in Ghana: a fully modified least squares approach

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Abstract

Purpose – This paper seeks to provide empirical insight into how industrialization and technology affect environmental quality in Ghana.

Design/methodology/approach – Using Ecological Footprint (ECF) as a measure of environmental degradation, the authors employ annual data from World Development Indicators of the World Bank and the Global Footprint Network spanning from 1970 to 2017 and apply the fully modified least squares (FMOLS) technique.

Findings – The results reveal that industrialization has a negative significant influence on ECF, suggesting that industrialization contributes to environmental sustainability in Ghana. The authors find that technology is harmful to the environment as it has a positive significant effect on ECF. The study also documents that while education and financial development improve environmental sustainability, fossil fuel consumption exacerbates environmental degradation in Ghana.

Originality/value – The environmental impact of industrialization is still being debated, with very scanty empirical evidence in the African context. Based on a detailed review of the literature, this paper provides an initial attempt to investigate the industrialization–environmental sustainability nexus in Ghana. Besides, whereas most extant studies have employed CO_2 emission as a proxy of environmental degradation, the authors use ECF to gauge the level of environmental degradation which is regarded as a more inclusive metric.

Keywords Industrialization, Technology, Ecological footprint, FMOLS, Ghana

Paper type Research paper

1. Introduction

Climate change has been one of the most pressing concerns in recent decades. As accentuated by the Intergovernmental Panel on Climate Change (IPCC), the most prominent contributor to greenhouse gas (GHG) emissions linked to climate change has been carbon dioxide emissions (Rjoub *et al.*, 2021). The surge in GHG emissions has raised great disquiet among policymakers globally. International treaties, such as the United Nations Framework Convention on Climate Change, require governments to develop policies and make efforts to reduce climate change and improve global environmental sustainability.

Given this context, it is critical to identify the fundamental factors influencing environmental pollution in order to develop practical policies that would improve environmental quality.

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Several attempts have been made in the literature to uncover the causes of environmental pollution, with conflicting results (Mesagan and Nwachukwu, 2018; Omri *et al.*, 2019; Shaheen *et al.*, 2020; Ur Rehman and Zeb, 2020; Chien *et al.*, 2021; Khalid *et al.*, 2021; Rjoub *et al.*, 2021; Tahir *et al.*, 2021; Burki and Tahir, 2022; Chu, 2022). Undoubtedly, the extant studies have identified numerous factors including economic and demographic factors as drivers of environmental degradation. The environmental effects of industrialization have also been subjected to empirical investigations. While most studies contend that industrialization is harmful to the environment (see Brahmasrene and Lee, 2017; Liu and Bae, 2018; Anwar *et al.*, 2020; Jermsittiparsert, 2021; Ahmed *et al.*, 2022), there is little evidence to imply otherwise (Zhou *et al.*, 2013; Opoku and Boachie, 2020). Despite the controversy over the industrialization–environment nexus, there are few empirical arguments in the African context and practically no study in Ghana on this subject matter. The scarcity of research on the relationship between industrialization and environmental sustainability in Africa may be attributed to the lack of data for most countries.

Recent discussions on economic strategy in Africa have focused heavily on industrialization as a means of combating the continent's persistent poverty and reversing the region's long history of underdevelopment (Opoku and Aluko, 2021). Consequent to this, some African countries have established a range of industrial strategies to jumpstart their industrialization efforts. For example, Ghana launched the One District One Factory (1D1F) program in 2017, intending to put up a manufacturing facility in each of the country's 261 districts to increase employment in the manufacturing sector, diversify the local economy, and enhance growth. Perhaps this is in recognition of the enormous potential of the industrial sector to accelerate Ghana's economic growth. For instance, the industry generated 29.74% of the country's overall GDP in 2020 (O'Neill, 2022). By offering job opportunities, the sector has also contributed to the reduction of unemployment and provides critical linkages and resources for other sectors of the national economy. Despite the fact that the industrial sector is vital to national growth, its environmental impact cannot be overlooked. From a sustainable development standpoint, we argue that whilst the pursuit of growth through industrialization is important, the ability to continue to do so into the foreseeable future is paramount, and as noted by Klarin (2018), sustainable development is based on redistribution of resources to ensure the quality of life for all including future generations. As a result, environmental sustainability which is focused on maintaining the quality of the environment is essential in ensuring that the pursuit of economic growth today does not compromise the quality of life now and in the future. This study, therefore, seeks to examine whether industrialization inhibits or promotes environmental sustainability in Ghana.

In addition to industrialization, the study examines the relationship between technology and environmental quality. Scholarly research has documented mixed results on the effect of technology on pollution. While some researchers (see Adebayo and Kirikkaleli, 2021; Yakubu *et al.*, 2021; Wahab *et al.*, 2022) evidenced that technology exacerbates environmental pollution, other studies (for example Bin and Shuo, 2017; Ahmad et., 2020; Chen *et al.*, 2020; Nguyen *et al.*, 2020; Niu, 2021; Paramati *et al.*, 2021) argued that technology enhances environmental quality. This study seeks to advance the debate on the technology–environmental sustainability nexus in the case of Ghana.

Our paper adds to the existing literature in three ways. First, empirical studies on the drivers of environmental pollution have gained momentum in recent decades. However, most of the existing studies in Ghana have predominantly used carbon dioxide emission to gauge pollution, which fails to deliberate on resources such as oil, forest, mining, soil and fishing. Given the weakness of this measure, the present study employs Ecological Footprint (ECF) to measure environmental pollution. This indicator considers the effect of anthropogenic actions with respect to carbon, fishing, forest, soil, air, and land, and is therefore regarded as an appropriate and inclusive proxy for environmental pollution. Second, the study augments the very scanty attempts on the impact of industrialization on environmental sustainability in developing economies, particularly on country-specific analysis. Additionally, the paper contributes to the understanding of the ecological modernization theory (EMT). That is, we test the validity of the EMT in the context of a developing country.

The rest of the work is organized as follows: Section 2 provides a brief overview of industrial evolution in Ghana. Section 3 reviews the literature. In Section 4, we outline the research methodology. Section 5 presents and discusses the empirical results. Section 6 concludes and Section 7 provides some recommendations.

2. Ghana's industrial evolution in brief

Ghana has strived to develop the manufacturing sector of the economy since independence, with the objective of becoming an industrialized nation. The country has experienced three significant industrialization phases since independence, namely the inward over-protected ISI strategy (1960–1983), the outward liberalized strategy (1984–2000) and the private sector-led accelerated industrial development strategy of 2001 and onward (Ackah *et al.*, 2014). The ISI strategy (1960–1983) was primarily focused on the creation of large-scale, capital-intensive state-owned manufacturing industries. The government made significant investments in infrastructure and was involved in the domestic production of previously imported consumer goods, the processing of primary product exports (agricultural and mining), and the development and expansion of industries like building materials, electrical, electronics and machinery. The expansion of these industries was meant to supply the inputs required for the growth of the industrial sector (Steel, 1972). The ISI strategy was self-limiting given that the effective protection afforded to industries under the ISI strategy rendered such import-dependent industries unproductive in utilizing the available domestic resources. Between the mid-1970s and 1983, the industrial sector and the Ghanaian economy in its entirety experienced a significant downturn in economic performance as a result of external shocks and ineffective domestic policies. In April 1983, the Economic Recovery Program (ERP) was launched as part of the Structural Adjustment Program (SAP) with the goal of reversing the downturn in all sectors of the Ghanaian economy, as well as rehabilitating wrecked productive and social infrastructure. The SAP/ERP also intended to rectify Ghana's structural macroeconomic imbalances by revamping practically all sectors including the industrial sector. Some important economic policy reforms implemented under the SAP included: the elimination of price and distribution controls, the abolition of import licensing, and the use of market-determined prices; the privatization of state-owned enterprises (SOEs) initiated in 1988; and industrial policies to assist distressed but potentially viable SOEs introduced in the early 1990s. Shortly after the ERP was implemented, the industrial sector, particularly the manufacturing sector responded positively to the reforms, laying the groundwork for quick recovery of the industrial sector after a decade of contraction. The focus of Ghana's industrialization strategy changed over the first half of the 2000s. During that time, the emphasis was on stabilizing the economy and developing the foundation for a sustainable and job-creating agro-based industrial sector. The industrial sector's policy measures included strengthening agricultural marketing, expanding access to export markets, fostering the development of domestic and export-oriented businesses in rural areas, and boosting the marketability of domestic industrial products. These initiatives received a positive response from the industrial sector. Following these industrial growth strategies, various Ghanaian governments have stepped up their efforts over the last few decades to improve the productive base of Ghana's economy, particularly by boosting manufacturing activities.

3. Literature review

3.1 Underpinning theory

This study is based on the EMT. EMT has emerged as a fundamental neoliberal theory and one of the most influential environmental sociology theories (York and Rosa, 2003). The EMT's goal has been to examine how modern industrialized societies deal with environmental challenges (Mol and Sonnenfeld, 2000). As per the premise of the EMT, continuing industrial growth, rather than unavoidably degrading the environment, is the optimal way to avoid global ecological challenges. The theory demonstrates a nonlinear relationship between environmental quality and industrialization. It contends that environmental quality declines during the early stages of modernization when industries are not fully developed (Rehman *et al.*, 2022). In the long run, industries' access to cutting-edge and environmentally friendly technologies becomes much more manageable as they develop, and therefore their contribution to environmental degradation tends to decrease (Bergendahl *et al.*, 2018).

3.2 Empirical literature

In the literature, several factors have been noted as drivers of environmental pollution. Given the aim of this study, we discuss the empirical studies on the effect of industrialization and technology on environmental quality.

3.2.1 Environmental effect of industrialization. According to empirical assumptions, the industrialization process is linked with increased energy consumption (Pan *et al.*, 2019). As a result, industrial activities may contribute to pollution and, therefore, climate change. The linear effect of industrialization on environmental quality has been examined in the literature. For instance, Ahmed *et al.* (2022) revealed that environmental pollution in the Asia–Pacific region is positively and significantly driven by industrialization. Along similar lines, Jermsittiparsert (2021) found that industrial growth and environmental degradation in the ASEAN countries are positively related. Applying the autoregressive distributed lag (ARDL) technique, Liu and Bae (2018) evidenced that industrialization significantly increases CO_2 emissions in China. Employing a sample of 33 Belt and Road Initiative countries with the pooled mean group (PMG) method as an analytical technique, Anwar *et al.* (2020) indicated that industrialization increases environmental degradation. All these studies are consistent with the empirical assumptions about the negative effects of industrialization on the quality of the environment. But there is no tidy conclusion on this. For instance, Opoku and Boachie (2020) showed an insignificant impact of industrialization on environmental pollution in Africa. Similarly, Nasir *et al.* (2021) established that there is no significant influence of industrialization on environmental degradation in Australia. Employing the STIRPAT model, Nasrollahi *et al.* (2020) reported that environmental quality is negatively influenced by industrialization in the MENA and OECD countries. Applying the generalized method of moments technique with data from 29 provinces in China, Zhou *et al.* (2013) revealed that industrialization contributes to enhancing environmental quality.

Interestingly, some studies document that the link between industrialization and environmental pollution is nonlinear. For instance, Li *et al.* (2019) revealed that while industrialization increases environmental pollution in the initial stages, environmental degradation is decreased by the growth in industrialization at the intermediate stage. Beyond the intermediate stage, environmental quality is again diminished due to industrial activities. Using the nonlinear ARDL model, Mahmood *et al.* (2020) demonstrate that industrialization asymmetrically influences environmental pollution in Saudi Arabia. This suggests that a positive shock of industrialization degrades the environment more than a negative shock. Munir and Ameer (2020) found that increasing industrialization leads to increased pollution levels, whereas decreasing industrialization has no effect on pollutant emissions in Pakistan.

3.2.2 The impact of technology on environmental quality. The effect of technology on environmental pollution remains ambiguous given the mixed empirical findings. While some studies show that technology lessens pollution, others contend that technological advancement accelerates environmental degradation. For example, using data from 95 economies spanning from 1996 to 2007, Li and Wang (2017) documented that technological change lessens environmental pollution. Using the STIRPAT model with annual data covering the years 1997–2015, Yu and Du (2019) found that technological innovation contributes to mitigating CO_2 emissions in China. Razzaq *et al.* (2021) also investigated the impact of tourism and technological innovation on CO_2 emissions in China. Invoking the Quantile ARDL approach, the researchers observed that technological innovation reduces CO_2 emissions in the long-run. Anwar *et al.* (2021) reported that CO_2 emission is significantly reduced by increasing technological innovation in the G7 countries over the period 1996–2018. In the case of Iran, Shahnazi and Dehghan Shabani (2019) established an inverted U-shaped relationship between information technology and CO_2 emission. This suggests that the growth in information technology initially increases environmental pollution up to a point, and after this point, pollution decreases with an improved level of information technology. Lu (2018) demonstrated that the advancement of information technology significantly contributes to the reduction of CO_2 emissions in some selected Asian economies. Khan *et al.* (2022) reported that an improved level of information technology lessens environmental pollution in Morocco. Employing data from 73 developing economies covering the period 1990–2016, Jahanger *et al.* (2022) evidenced that technological innovation enhances environmental quality.

On the contrary, Khan *et al.* (2018) noted that information technology reduces environmental quality, particularly through its interaction with financial development. Using the PMG technique with data spanning from 2001 to 2014, Park *et al.* (2018) revealed that information technology in the form of Internet usage inimically affects environmental quality in selected European Union (EU) economies. By applying the panel vector autoregressive estimator, Charfeddine and Kahia (2021) indicated that information technologies increase environmental pollution in the MENA region. Amri *et al.* (2019) found no significant effect of information technology on environmental pollution in Tunisia. Employing the quantile regression technique, Adebayo *et al.* (2022) showed a positive effect of information technology on environmental degradation in the Netherlands, South Korea, and Iceland.

In examining the drivers of environmental pollution, anthropogenic gas emissions (precisely CO_2) are widely employed to measure the level of environmental pollution in the literature. Notwithstanding the fact that the emissions of anthropogenic gas significantly contribute to climate change, they do not fully reflect the degree of environmental degradation in a particular setting, given that it ignores how most human activities affect the ecosystem. Therefore, we use ECF which is considered a more comprehensive proxy of environmental degradation. Also, there are no studies explaining how industrialization affects environmental quality specifically in Ghana. Thus, this study seeks to fill this gap in the literature.

4. Methodology

4.1 Data and variables

The study uses annual data covering the years 1970–2017. ECF serves as the dependent variable. ECF is captured as "a composite of six dimensions comprising carbon, build-up land, grazing land, fishing grounds, forest products and cropland" in gha per person terms. Extracts of the ECF data used for the analysis are presented in Table 1. Although ECF is regarded as a comprehensive measure of environmental pollution, it is not without limitations. For instance, ECF estimation is based on hypothetical land, which does not reflect

Footprint	Description
Built-up land	"The built-up land Footprint is calculated based on the area of land covered by human infrastructure — transportation, housing, industrial structures, and reservoirs for hydropower. Built-up land may occupy what would previously have been cropland"
Carbon	"The carbon Footprint component of the Ecological Footprint is calculated as the amount of forest land needed to absorb these carbon dioxide emissions"
Cropland	"The cropland Footprint includes crop products allocated to livestock and aquaculture feed mixes, and those used for fibers and materials"
Fishing grounds	"The fishing grounds Footprint is calculated based on estimates of the maximum sustainable catch for a variety of fish species"
Forest products	"The forest product Footprint is calculated based on the amount of lumber, pulp, timber products, and fuel wood consumed by a country on a yearly basis"
Grazing Land	"The grazing land Footprint is calculated by comparing the amount of livestock feed available in a country with the amount of feed required for all livestock in that year, with the remainder of feed demand assumed to come from grazing land"

Source(s): Global footprint network

Table 1. Extracts of the ecological footprint data

the actual land use (Budihardjo *et al.*, 2013). It also simplifies natural resource utilization. Likewise, ECF does not account for exports and imports.

The main independent variables include industrialization and technology while we control for the effect of education, financial development and fossil fuel consumption. Following the works of Shahbaz *et al.* (2018) and Akçay (2019), we measure industrialization using manufacturing value added (% of GDP). In line with Yakubu *et al.* (2021), the interaction term of industry sector value-added and services sector value-added is used to gauge technology. For the control variables, education is proxied by the percentage of gross enrollment in secondary school. Financial development is measured by domestic credit to the private sector (% of GDP) and fossil fuel consumption is the amount of fossil fuel used (as a percentage of total energy consumption). Except for ECF data which is obtained from the Global Footprint Network, data for the rest of the variables are gleaned from the World Development Indicators (WDI) of the World Bank (2018). The WDI is a collection of relevant, quality and globally comparable data on world development. It compiles data on 1,400 time series indicators for 217 countries and more than 40 country groups.

4.2 Empirical model

Following the work of Yakubu *et al.* (2022a), the basic empirical model for analyzing the impact of industrialization and technology on environmental pollution is specified as follows:

$$ln\mathrm{ECF}_t = \alpha_0 + \beta_1 ln\mathrm{IND}_t + \beta_2 ln\mathrm{TEC}_t + \beta_3 ln\mathrm{EDU}_t + \beta_4 ln\mathrm{FID}_t + \beta_5 ln\mathrm{FOS}_t + \varepsilon_t \quad (1)$$

where t indicates the time dimension and α and β are the intercept and coefficients of the explanatory variables. ε denotes the error term. ECF, IND, TEC, EDU, FID and FOS are acronyms for ECF, industrialization, technology, education, financial development and fossil fuel consumption respectively. All variables are in the natural logarithm.

4.3 Estimation technique

The study applies the fully modified least squares (FMOLS) technique in the data analysis. In comparison with alternative least-squares techniques, the FMOLS technique offers superior results and addresses the problem of biased estimates (Yang *et al.*, 2021; Yakubu *et al.*, 2022b). Prior to the model estimation, the study checked for stationarity of the variables to ensure accurate model estimates. In doing so, the Augmented Dickey–Fuller unit root test is used.

The Johansen cointegration test is also used to check if the variables have a long-term relationship. The researchers employ EViews version 10.0 to perform the regression analysis.

5. Empirical results

5.1 Descriptive statistics

Table 2 provides the descriptive statistics of the variables in their nonlogarithm form. ECF has an average of 0.7507 with minimum and maximum values of 0.4481 and 1.2777, respectively. Industrialization has low volatility among the independent variables given the lowest standard deviation value. Additionally, the variables display positive skewness, with the exception of industrialization. The kurtosis values of technology and education are greater than 3, indicating a leptokurtic distribution. The Jarque–Bera test results show that ECF, industrialization, technology and financial development are normally distributed at 5% level of significance.

5.2 Stationarity test results

The Augmented Dickey–Fuller (ADF) unit root test is used to determine the order of integration of the variables before testing for cointegration. To reduce biases in the estimation, it is critical to eliminate all variables showing second-order integration. Table 3 presents the results of the unit root test. The test results show that all the variables are stationary at first difference, and therefore require no second-order integration.

5.3 Cointegration test

The Johansen cointegration test is used in the study to see if there is a long-term relationship among the variables. From Table 4, the Trace test and the Max-eigenvalue test show that there are two and one cointegrating equations respectively, and therefore an indication that the variables have a long-run relationship.

	ECF	IND	TEC	EDU	FID	FOS
Mean	0.7507	8.5427	718.3180	41.1631	26.0064	29.2079
Maximum	1.2777	13.9504	1364.7480	69.0092	39.2976	52.6160
Minimum	0.4481	3.6055	208.7130	33.2982	16.3827	11.5289
Std. Dev.	0.2757	2.4270	278.1739	10.7631	5.4410	13.2172
Skewness	0.5442	−0.3011	0.6782	1.7315	0.3078	0.7052
Kurtosis	1.8107	2.6770	3.1580	4.5413	2.5542	1.9388
Jarque–Bera	5.1979	0.9338	3.6515	26.9399	1.1552	6.1015
Probability	0.0744	0.6269	0.1611	0.0000	0.5612	0.0473

Table 2.
Descriptive statistics

	Level		First difference	
	t-statistic	Prob.	*t*-statistic	Prob.
*ln*ECF	0.5954	0.9882	−6.5816	0.0000***
*ln*IND	−1.9473	0.3083	−5.6343	0.0000***
*ln*TEC	−0.6670	0.8444	−4.6364	0.0000***
*ln*EDU	1.2492	0.9980	−6.8905	0.0000***
*ln*FID	−2.5841	0.1034	−7.1743	0.0000***
*ln*FOS	−0.0718	0.9462	−9.3807	0.0000***

Note(s): *** indicates stationarity at and 1%

Table 3.
Augmented Dickey–Fuller (ADF) unit root test results

Cointegration test based on trace of the stochastic matrix				
Hypothesized no. of CE(s)	Eigenvalue	Trace statistic	0.05 critical value	Prob.**
None *	0.6272	120.3995	95.7537	0.0004
At most 1 *	0.5974	80.9318	69.8189	0.0050
At most 2	0.3712	44.5362	47.8561	0.0992
At most 3	0.3136	25.9813	29.7971	0.1293
At most 4	0.2366	10.9304	15.4947	0.2158
At most 5	0.0033	0.1316	3.8415	0.7167
Cointegration test based on maximal eigenvalue of the stochastic matrix				
Hypothesized no. of CE(s)	Eigenvalue	Max-eigen statistic	0.05 critical value	Prob.**
None	0.6272	39.4677	40.0776	0.0584
At most 1*	0.5974	36.3956	33.8769	0.0245
At most 2	0.3712	18.5549	27.5843	0.4497
At most 3	0.3136	15.0509	21.1316	0.2854
At most 4	0.2366	10.7988	14.2646	0.1646
At most 5	0.0033	0.1316	3.8415	0.7167

Note(s): Trace test and Max-eigenvalue test indicate 2 and 1 cointegrating equations respectively
*denotes rejection of the hypothesis at the 0.05 level
**MacKinnon–Haug–Michelis (1999) *p*-values

Table 4.
Cointegration results

5.4 Regression results

In Table 5, we report the results of the FMOLS estimation. The findings indicate that the coefficient of industrialization is negative and statistically significant. This shows that industrialization's impact on the environment is not detrimental but rather a way to slow down environmental deterioration in Ghana. The finding implies that notwithstanding Ghana's increased industrialization drive, notably manufacturing activities, the environmental policies aimed at reducing pollution are commendable. The Partnership for Action on Green Economy, for example, is one of the main strategies for achieving environmental sustainability in Ghana through the implementation of appropriate

Variables	ECF
*ln*IND	−0.6751***
	(0.0804)
*ln*TEC	0.8172***
	(0.0710)
*ln*EDU	−1.2818***
	(0.1591)
*ln*FID	−0.1637**
	(0.0673)
*ln*FOS	0.4476***
	(0.0611)
C	−0.1947
	(0.1974)
R-squared	0.9515
Adj. *R*-squared	0.9448
S.E. of regression	0.0355
Long-run variance	0.0009

Note(s): Values in ( ) are standard errors *** is statistical significance at 1%

Table 5.
Fully modified OLS (FMOLS) estimates

regulations to prevent environmental pollution from industrial activities. Industrialization, in practice, impacts the environment inimically. So, our result markedly refutes this presumption and the findings of earlier studies that demonstrate that industrialization has a negative effect on the environment (Brahmasrene and Lee, 2017; Liu and Bae, 2018; Anwar *et al.*, 2020; Jermsittiparsert, 2021; Ahmed *et al.*, 2022). The finding is however consistent with that of Opoku and Boachie (2020), who discovered that environmental pollution in Africa is not driven by industrialization. Also, the long-term negative relationship between industrialization and environmental pollution lends credence to the EMT which postulates that in the long run, industries' access to cutting-edge and environmentally friendly technologies becomes much more manageable as they develop, and therefore their contribution to environmental degradation tends to decrease.

Our findings show that technology exerts a positive significant effect on environmental degradation. More precisely, a percentage increase in technology exacerbates environmental degradation by 0.817%. The result suggests that in the drive to boost domestic output with the adoption of advanced technologies, energy consumption rises, increasing environmental degradation. The findings support those of Lv and Xu (2019) and Yakubu *et al.* (2021).

Education has a negative significant impact on ECF, implying that environmental quality is enhanced with increasing level of school enrollment in Ghana. The intuition is that an improvement in educational attainment may contribute to higher environmental awareness, aiding in the reduction of pollution-related activities. Education also encourages people to recognize the need for energy conservation and to explore alternative energy sources, thus reducing environmental pollution. Empirically, our finding agrees with some prior studies (see Zafar *et al.*, 2022; Li *et al.*, 2021; Liu *et al.*, 2022).

The impact of financial development on ECF is negative, suggesting that financial sector development in Ghana contributes to lessening pollution. Financial development reduces pollution by funding research and development, which allows for the evolution of ecologically friendly technologies (Amin *et al.*, 2022). Our finding is comparable to prior research (Usman and Hammar, 2021; Abid *et al.*, 2022).

Consistent with the findings of Naseem *et al.* (2020) and Onifade *et al.* (2021), fossil fuel consumption has a significant positive impact on environmental degradation. This result can be explained by the claim that fossil fuel is a "dirty" source of energy that has adverse environmental impacts (Kwakwa and Alhassan, 2018).

6. Conclusion

The UN Climate Change Conference (COP26) 2021 assessed progress made in four key areas relating to climate change and sustainable development including mitigation, adaptation, finance and collaboration, noting that more needs to be done to combat climate change. Given the obvious link between environmental degradation and climate change and the ensuing negative impacts, concerns about ecological sustainability have received increased global attention. Climate change is currently a contentious issue since it endangers both sustainable and human growth. Climate change's consequences are more extreme in underdeveloped countries since they have poor mechanisms to deal with such issues. As a result of climate change, there has been an increase in climate extreme events including floods, droughts and windstorms, loss of biodiversity, and drying of water bodies. There is a case to be made for enhancing environmental sustainability in order to lessen the effects of climate change and ensure sustainable development. Over the last few decades, researchers have sought to investigate the key factors influencing environmental degradation with inconclusive findings. This study seeks to contribute to the growing debate by examining how industrialization and technology affect environmental degradation in Ghana. To comprehensively measure environmental degradation, we employ the ECF measure as an indicator of environmental degradation.

Applying the FMOLS technique, the results reveal that industrialization has a negative significant influence on ECF, suggesting that environmental sustainability is enhanced as industrial activities increase. In other words, industrialization helps in curtailing environmental degradation in Ghana, contrary to the generally held empirical assumptions about the negative effects of industrialization on environmental quality. We find that technology is harmful to the environment as it has a positive significant effect on ECF. For the control variables, the study establishes that while education and financial development contribute to environmental sustainability, fossil fuel consumption exacerbates environmental degradation.

7. Policy recommendations

Based on the findings, we provide policy suggestions. First, firms engaged in manufacturing should be urged to embrace and use more environmentally friendly technologies. Second, the state and relevant stakeholders should consider instituting subsidies for low-carbon technologies to promote the demand for such technologies. Third, to curb pollution and guarantee that industrial activities enhance environmental sustainability, environmental regulations need to be strictly implemented including the imposition of higher fines for infractions of environmental policies and rules. Finally, we recommend that financial institutions, other lenders and development partners should prioritize financing ecologically sustainable activities.

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