The Effect of Manufacturing activities and Economic Openness on CO_2 Emissions in Ghana: An Autoregressive Distributed Lagged Bounds Approach [⁕]

JEL Classification: Q56, Q50, Q53, F41, L60

Keywords: Environmental impact, Climate Change, Manufacturing, Trade openness, Carbon dioxide emissions, Bayer and Hanck combined cointegration, ARDL bounds test

Abstract

This study investigates the effect of manufacturing activities and economic openness on CO_2 emissions in Ghana for the period 1975 to 2014 using WDI data of the subsector. We conducted the Bayer and Hanck combined cointegration test to examine the short run and long run relationship. The ARDL bounds test was conducted to test the robustness of results. In this study, we accounted for the non-linearity of the production-emission relationship by modelling the environmental impact parameter which represented the contribution of foreign technology to environmental quality. This allowed us to test for the Environmental Kuznets Curve (EKC) hypothesis between the subsector's development and its emissions of CO_2 and we used the Lind and Mehlum second order test to confirm an inverted U-shape relationship. The results revealed that manufacturing trade positively affects the sector's emission of CO_2 in the long and short run. The results also suggest a positive relationship between manufacturing production and CO_2 emissions in Ghana and further analysis revealed an inverted U relationship which peaks early. Finally, there is no significant relationship between FDI inflows and the manufacturing sector and its CO_2 emissions. Our findings highlighted the need for trade and industrial policies that prevent the dumping of manufacturing goods in Ghana while promoting local production of environmentally friendly manufacturing goods.

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1. Introduction

Climate change, global warming, and the general issue of environmental conservation have increasingly featured in policy discussions of many countries for more than three decades (Tsurumi and Managi 2010; Tang and Tan 2015). The increasing concerns for the unsustainable use of scarce natural resources and the associated damages to the environment, resulting from globalization, and widespread increase in economic activities have been documented in several international reports (UNEP 2012). This concern and many others birthed the sustainable development agenda with 17 sustainable development goals (SDGs) which remain the most comprehensive and inclusive worldwide focus on the global environment. Nonetheless, cross border activities including trade and capital flows continue to dominate the debate on emissions and environmental impacts in less developing countries (LDCs).

Several studies have investigated the impact of the fast-growing world-economy on the environment (Jorgenson, Stephens, and White 2019). This has created concern on how economic openness (trade and FDI flows) impact on the environment in developing countries who have recently been opening their economies to the rest of the world with the view of promoting economic growth and development. While previous investigations on the environmental effects of foreign direct investment (FDI), economic growth and international trade are extant in the literature, many of these studies appropriately focused on developing countries which are characterized by unfavourable terms of trade, lax environmental laws and where the stock of FDI inflows is highest. However, most of those studies employed sector-aggregated or macro-level data (Aboagye, 2017; Sarkodie & Strezov, 2018; Shahbaz et al., 2019; Twerefou et al., 2016). The results from these studies are generalized and not specific to any of the sub sectors of the economies, hence, resulting in misguided and inappropriate policy interventions towards FDI and trade related environmental sustainability as far as the sub-sector reforms are concerned. This is because FDI inflows are disproportionately distributed across sectors and some sectors are more traded on the international market than others. Hence, there is the need for subsector specific studies to help design appropriate policy interventions.

Growth in per capita income has been identified in previous studies as the primary driver of carbon dioxide emissions (Shahbaz, Nasir, and Roubaud 2018; Shahbaz et al. 2019). However, the importance of FDI and trade openness in carbon dioxide emissions cannot be overlooked, particularly from a developing country perspective. The poor compliance to environmental laws resulting from a weak regulatory system, the unfavourable trade policies, and the increasing competition amongst developing countries to attract FDI have severe socio-environmental consequences, albeit the benefits of technical transfers (Shahbaz et al. 2019) and improvement in the scale and composition of local production (Le, Duy, and Ngoc 2019).

Manufacturing has been one of Ghana's areas of focus to economic transformation and industrialization since independence. The sub sector has experienced increased attention in the political and socioeconomic discussions in the past few decades. The sector made significant positive strides in recent years amid the global disruptions resulting from the COVID-19 pandemic – witnessing continuous growth in 2020 and 2021 (Sodimu 2022). Despite the sector's attraction of most FDI inflows on average and constituting one of the most traded sub sectors on the international market, there has been limited efforts to study their impact on carbon dioxide emissions for feasible green interventions.

The rate of growth of FDI into manufacturing has been identified to outpace that of sectoral merchandise trade (Chen and Roberts 2010; Demena and Afesorgbor 2020). More so, increases in restrictive trade policies have influenced firms' choice of FDI as an entry strategy into many developing countries to produce directly for the domestic economy. Meanwhile, manufacturing trade continues to be an important contributor to economic growth, employment, technology and knowledge transfer, and poverty reduction vis-à-vis its implication for the international competitiveness of domestic firms (UNCTAD 2021).

In Ghana, most FDIs are largely into the industrial sector with the manufacturing subsector accounting for a considerable share of the inflows. While Ghana, like many developing countries implements policies and strategies to attract FDI through its investment promotion agencies (IPAs) to take advantage of the unarguable productivity spillovers (Harding and Javorcik 2007), the narrative is better placed when the environmental implications (emissions) are considered. Similar arguments are made for merchandize trade which displaces local competitiveness, impacts negatively on the foreign reserves, and promotes dumping (a common trade practice that impedes environmental growth for many trading developing countries). The weak environmental regulatory framework within developing countries and the unfavourable international trade arrangements with the developed world make the issue of in-country carbon dioxide emissions important and a matter of urgency for sustainable sector development, green FDI and green trade.

While studies on the effect of economic openness and energy sub-sector activities on emission are many, those on manufacturing are limited. Lessons from studies in the industrial sector in general becomes the starting point for any discussion on the industrial sub sectors like manufacturing. For Ghana, this is crucial, especially with the increasing pressure on the government to rejuvenate the manufacturing sub sector, the increasing manufacturing FDI inflows and merchandise trade, vis-à-vis the policy discussions on the contribution of industrialization to climate change and environmental sustainability. In this paper, we focus our attention on how the manufacturing sector activities and its openness to trade and FDI, impacts on carbon dioxide emissions in Ghana.

The rest of this paper is organized as follows. The next section presents a brief review of the related literature. The third section develops the model used for the study and discusses the data and the test approaches used for the empirical analyses. The fourth section presents the empirical analyses. The final section presents conclusions and offers policy implications.

2. Related Literature

The literature on the environmental implication of economic activities has focused mostly on internal factors (Shahbaz, Khraief, and Jemaa 2015; Adusah-Poku 2016; Shahbaz et al. 2016; Twerefou, Adusah-Poku, and Bekoe 2016; Adu and Denkyirah 2018) or external factors (Seker, Ertugrul, and Cetin 2015; Shahbaz et al. 2017, 2019; Pazienza 2019), and cases where attempts are made to consider the total factors (Aboagye, 2017; Huang et al., 2022), the theoretical relationships are not explicitly considered. The environmental Kuznets curve (EKC) hypothesis and the pollution haven/hallo hypothesis (PHH) are the two theoretical concepts mostly employed to explain the environmental effect of economic expansion resulting from total (local and international) activities. The EKC states a deteriorating effect of growth on the environment up to a point where further growth translates into improvement in environmental quality. The initial scale effect of growth from increases in economic activities results in environmental deterioration while the technique and composite characteristics of further growth help to boost environmental quality. Following the EKC hypothesis, the net effect of international trade and foreign investment activities is nonlinear. Similarly, the pollution haven hypothesis postulates that dirty companies in advanced countries may seek operational refuge in developing countries where the environmental laws are weak, hence, increasing emissions (Aller, Ductor, and Grechyna 2021). Nonetheless, the possibility of a pollution hallo hypothesis – an emission reduction scenario, is eminent when foreign companies or investors adopt stringent and environmental-adhering practices and approaches in their operations in host developing economies. Proponents of the hallo hypothesis purports that FDI makes available the needed clean and improved technologies for environmental sustainability (Grossman and Krueger 1995; Copeland and Taylor 2004)

The effect of FDI, and trade, on growth or pollution, particularly in the form of CO_2 emissions has been empirically examined at the macro level in the literature with mixed results either for countries (Seker, Ertugrul, and Cetin 2015; Zhang and Zhou 2016; Salahuddin et al. 2018; Mahadevan and Sun 2020; Nguyen 2020; Mahmood 2020; Sun et al. 2021) or cross-country panel analysis (Bernard and Mandal 2016; Huang et al. 2019, 2022; Pazienza 2019; Mahmood 2020). Huang et al, (2022) described

FDI inflows and carbon emission relationship as a matter of empirical controversy. However, many studies have provided evidence in support of the pollution haven hypothesis. For instance, single country studies by Mahadevan & Sun 2020) found that carbon emissions increase with expansions in FDI-led economic activities for China. Salahuddin et al. (2018) also reported positive association between FDI and carbon emission for Kuwait using the ARDL bounds testing approach. Seker et al. (2015) confirmed this phenomenon for Turkey using the ARDL and the error correction model (ECM) methodology. Other single country studies that confirmed the pollution haven hypothesis included Solarin et al. (2017) for Ghana and Sun et al. (2021) for China. On the contrary, some studies (Bölük and Mert 2015; Zhao et al. 2021) found evidence in validation of the pollution hallo hypothesis while Al-mulali & Tang (2013) found no significant impact of FDI on emission in the Gulf Cooperation Council countries.

Grossman & Krueger (1991) first explored the empirical relationship between trade and emissions, categorizing the effects into scale, technique, and composite. Subsequent studies on the environmental effect of trade have reported ambiguous findings (Adusah-Poku, 2016; and Kwakwa et al., 2019). Tiwari et al. (2022) found a positive relationship between trade openness and CO_2 emissions in India. Adusah-Poku (2016) reported similar findings for a study of Sub-Saharan African countries. Abokyi et al. (2021) employed the ARDL model to study the role of trade openness in electricity consumption and carbon emissions in Ghana. The study confirmed that trade openness contributes to carbon emissions. On the contrary, Kwakwa & Alhassan (2018), Kwakwa et al. (2019) and Boateng (2020) found that trade improves the environment by contributing to emission reduction in Ghana.

According to (Huang et al. 2019), previous studies on the environmental effect of FDI and trade have not considered economic growth as a key factors. For instance, Essandoh et al. (2020) investigated the environmental effect of trade and FDI on carbon dioxide emissions for different income groups for developing and developed countries. Their study found a positive long-run relationship between FDI and CO_2 emissions for low-income countries, and a negative long-run relationship between trade openness and CO_2 emissions for high-income countries. Nonetheless, their studies did not consider the direct role of growth in income per capita on CO_2 emissions.

The theoretical relationship between growth and emissions has been extensively examined and the idea adopted in environment economics both theoretically and empirically, with more recent studies testing for the curvature of the relationship using the Lind & Mehlum (2010) second order test for inverted U-shape or otherwise. In an empirical study of the environmental Kuznets, Sarkodie & Strezov (2018) confirmed an inverted U-shaped relationship between per capita income and CO_2 emissions for Australia and China, inverted N-shape for USA, but a monotone relationship in the case of Ghana. Sarkodie & Strezov (2019) conducted a meta-analysis and bibliometric analysis on the EKC hypothesis using EKC results and the associated turning points for each study. According to the authors, the studies that confirmed EKC had an average income of US$8910 at their turning points. Hence, they concluded that for developing countries like Ghana, it is more likely to continue experiencing declines in environmental quality with increased growth. In an early study, Twerefou et al. (2016) reported a U-shape relationship between per capita income and CO_2 emissions from an ARDL bounds test approach on a 1970 to 2010 Ghana dataset. Their study suggested the non-existence of EKC for Ghana. Aboagye (2017) confirmed the non-existence of EKC for Ghana in a study of the environmental impact of economic expansion (increase in GDP per capita) using the ARDL bound testing approach on a time series data spanning 1975 to 2015.

The inconclusion on the EKC hypothesis for Ghana becomes more evident in two recent and related studies by Abokyi et al. (2021). Abokyi et al. (2019) found results in validation of the EKC hypothesis between industrial growth and CO_2 emissions. Nonetheless, Abokyi et al. (2021) did not confirm the EKC hypothesis for a 1971 to 2014 time series data. The later study which focused on the role of the manufacturing sector in the relationship between electricity consumption and CO_2 emissions also adopted the Bayer and Hanck cointegration test and the ARDL bound testing procedure yet reported a U-shaped relationship between manufacturing output and CO_2 emissions.

The EKC hypothesis maintains its theoretical soundness on the possible relationship between economic expansion and environmental quality despite the inconclusion in empirical results and the confounding issues raised by Antweiler et al. (2001). That, in the absence of regulatory differences between the developed and developing countries, there exists a comparative advantage in the production of pollution goods in favour of the developed countries since the capital-intensive production in developed countries are more polluting (Aboagye 2017). This bias the extend of viability of the EKC hypothesis between the developing and developed countries as remarked by Sarkodie & Strezov (2019).

Our paper discusses the implication of internal and external economic activities for environmental sustainability with specific reference to Ghana’s manufacturing subsector. In this paper, we investigate the short run and long run effects of FDI, trade, and manufacturing production on CO_2 emissions. We also test the EKC hypothesis for growth of manufacturing and its emission of CO_2. Hence, we adopt a non-linear emission-production model which allows for the test of the second order condition for U-shape or inverted U-shaped relationship between manufacturing value added and CO_2 emission by the subsector.

3. Method

3.1 Model Specification

The production of manufacturing output is represented by the conventional technology-augmented production function modelled on the transformation of production inputs and technology into output. This is represented by the constant returns to scale Cobb-Douglas production function represented by equation 1 below:

$$V_t = f\left(A_t, L_t, K_t\right) = A_t\left(L_t^{\alpha} K_t^{1-\alpha}\right), \qquad 1$$

where V_t, A_t, L_t and K_t represent manufacturing real output (manufacturing value added), technology, labour, and capital at time *t* respectively. Based on the theoretical intuition that emission occurs because of economic activities (production), we transformed equation 1 from output production into carbon dioxide emission. This allows us to formulate a relationship between manufacturing production and emission and captures the effect of sectorial external activities and technology on carbon dioxide emission represented by the production-emission parameter θ.

$$E_t = \theta V_t^{\gamma} = \theta_t\left[A_t\left(L_t^{\alpha} K_t^{1-\alpha}\right)\right]^{\gamma} \qquad 2$$

where E_t is CO_2 emissions from manufacturing at time *t* (measured in kilotons), hereafter referred to as emissions or CO_2 emissions. V_t and θ are as already defined. The relationship in equation **Error! Reference source not found.** is nonlinear because it is expected that the relationship between manufacturing output and emission differs depending on the level of development. A typical developing country attracts technology from other countries particularly the advanced ones. Hence, we model the environmental impact parameter (output-emission parameter) to represent the contribution of foreign technology to environmental quality. From equation **Error! Reference source not found.** we can categorize the factors of emissions into internal and external sources, and condition them on the efficiency of both the internal (A) and externally (θ) driven technology within the manufacturing sub-sector.

Cross-border trade and foreign investments are the two major variables identified in the literature to influence technology in developing nations like Ghana. Foreign trade necessitates the inflow of knowledge and skills to boost economic activities in the sector, albeit its associated negative impact on many developing countries (European Investment Bank. 2020). In the manufacturing sector of Ghana, FDI is an important capital investment, and a key variable for industrial growth and emission. According to (Keho 2017), technological progress is determined by trade openness. However, we believe that the overall economic openness which is made up of trade and FDI openness is important for the manufacturing sub sector. Hence, we augment Keho's (2017) model of technological progress by including FDI as a factor of technology into the sector.

$$\theta = \Omega T_t^{\xi_1} I_t^{\xi_2} Z_t^{\xi_3} \qquad 3$$

$T_t = \frac{(Xm_t + Mm_t)}{Trade_t}$ represent manufacturing trade intensity, I represent foreign direct investment into manufacturing, and Z stands for other factors that may determine the state of technology (Keho, 2017). Xm, Mm and $Trade$ are manufacturing export, manufacturing import, and total trade respectively (all measured in USD). Like trade openness, trade intensity encapsulates sector innovativeness as it promotes the transfer of technical know-how (Barro and Sala-i-Martin 1995; Keho 2017). We substitute equation 3 into equation **Error! Reference source not found.**, and formulate the emission function as:

$$E_t = \theta V_t^{\gamma} = (\Omega T_t^{\xi_1} I_t^{\xi_2} Z_t^{\xi_3}) V_t^{\gamma} \qquad 4$$

We integrate $Z_t^{\xi_3}$ into the error term and apply the natural logarithm to obtain the following econometric model:

$$\ln E_t = \beta_0 + \beta_1 \ln \mathrm{T}_t + \beta_2 \ln \mathrm{I}_t + \beta_3 \ln \mathrm{V}_t + \mu_t \qquad 5$$

$\beta_1 = \Omega\xi_1$ and $\beta_2 = \Omega\xi_2$ and $\beta_3 = \Omega\gamma$

The log-form specification is used to obtain the elasticities of emission which are more intuitive and easier to interpret. We add the squared term of manufacturing output $[(lnV_t)^2]$ to equation **Error! Reference source not found.** to test for the EKC hypothesis on manufacturing growth and the sub-sector emission of CO_2. This is represented in equation 6 below.

$$\ln E_t = \beta_0 + \beta_1 \ln \mathrm{T}_t + \beta_2 \ln \mathrm{I}_t + \beta_3 \ln \mathrm{V}_t + \beta_4 (\ln \mathrm{V}_t)^2 + \mu_t \qquad 6$$

EKC is one of the most referenced hypotheses in environmental studies. It hypothesizes an inverted U-shaped relationship between the level of economic development (per capita income) and environmental degradation. At the initial stages of development, the EKC hypothesizes an increased pressure on the environment in all forms resulting in degradation of environmental quality. However, beyond a certain threshold of development (increase in income per capita), there is high demand for a quality environment because people can now afford quality, hence improvement in environmental quality (decrease in degradation). The implication is that economic development translates into improvement in environmental quality at higher income levels (Demissew Beyene and Kotosz 2020; Wen and Dai 2021; Ullah et al. 2021; Bandyopadhyay and Rej 2021). Against the background of this hypothesis, three major studies on EKC are evident in literature based on the findings. Studies that provide empirical evidence in support of the EKC hypothesis (Ben Zaied, Ben Cheikh, and Nguyen 2017; Barra and Zotti 2018; Sinha and Shahbaz 2018; Armeanu et al. 2018; Usman, Iorember, and Olanipekun 2019; Demissew Beyene and Kotosz 2020; Wen and Dai 2021); studies that do not support the hypothesis (Adu and Denkyirah 2018; Zambrano-Monserrate et al. 2018; Asumadu-Sarkodie and Yadav 2019; Bandyopadhyay and Rej 2021); and studies that provide mixed results – the EKC assumption was confirmed for some emission types and/or countries but not for other emissions or countries (Ali et al., 2016; Cetin, 2018; Sica, 2014).

3.2 Data and Approach

The study uses annual time series data for Ghana obtained from the World Development Indicator (WDI). The data span the period 1975 to 2014 due to data availability for the key variable of analysis (carbon dioxide emission from manufacturing). Particularly, CO_2 emissions from manufacturing with missing values for the years 2015 to 2020. The time series properties are examined by using different unit root testing approaches -first, the traditional ADF and Phillips Perron test, to examine the time series properties of the data and use the Zivot & Andrews (2002) and Clemente-Montanez-Reyes unit root tests (Clemente, Montañés, and Reyes 1998) for single and multiple breaks respectively. We then used the Bayer & Hanck (2013) cointegration approach to examine the long run relationship and used the ARDL bounds testing approach as a robust test.

3.3 Unit Root Test

Conducting regression analysis with non-stationary variables could result in spurious estimates (Appiah-Konadu et al. 2016; Shitsi and Gakpey 2017; Murshed et al. 2020; Osabuohien-Irabor 2020; Lin and Tu 2020). We therefore examined the time series properties of the variables for unit root. The conventional Augmented Dickey-Fuller (Dickey and Fuller 1981) and Phillips & Perron (1988) unit root test were carried out. However, these tests have come under functional criticisms (Murshed 2021). While time-series data are more volatile and susceptible to breaks, the ADF approach does not account for structural breaks (Murshed et al. 2020; Murshed 2021) and the Perron test on the other hand determine these breaks exogenously (Zivot and Andrews 2002). Although the ADF and Perron tests are carried out as a preliminary test of stationarity, the study also employed the Zivot & Andrews (2002) and Clemente et al. (1998) tests which are considered robust and efficient over the ADF and Perron tests.

The Zivot-Andrew approach considers single structural breaks in time series which are endogenously determined. The Clemente et al. (1998) formulation on the other hand allows for two endogenous structural breaks (Ridderstaat and Croes 2015) and can distinguish sudden changes and gradual shifts in the series – the former captured by the innovative outliers and the later by the additive outliers (Oduber, Ridderstaat, and Martens 2015). The Clemente et al. (1998) approach is implemented to confirm the outcome of the Zivot & Andrews test. If the stationarity properties change significantly with the former approach, we conclude that the series has multiple breaks, hence, we base proceeding analysis on that outcome.

3.3.1 Zivot-Andrew Unit Root Test

The intuition behind the Zivot-Andrew is to choose the break time that minimizes one-sided t-statistics of α=1 in the alternate hypothesis stated in equations *7-9* below, asserting an endogenously determined break time by sequential estimation of the three equations representing the alternate hypotheses. Thus, this approach endogenizes one structural break in a series (say y_t) following the alternate hypothesis (Model A, B and C) in equation 7, 8, and 9 respectively below, against the null (H_0: $y_t = \mu + y_{t-1} + e_t$) which accounts for changes in the intercept and the trend break.

Model A $$\Delta y_t = c + \alpha y_{t-1} + \beta t + \theta DU_t + \sum_{j=1}^{k} h_j \Delta y_{t-j} + \varepsilon_t \tag{7}$$

Model B $$\Delta y_t = c + \alpha y_{t-1} + \beta t + \gamma DT_t + \sum_{j=1}^{k} h_j \Delta y_{t-j} + \varepsilon_t \tag{8}$$

Model C $$\Delta y_t = c + \alpha y_{t-1} + \beta t + \theta DU_t + \gamma DT_t + \sum_{j=1}^{k} h_j \Delta y_{t-j} + \varepsilon_t \quad 9$$

DU_t and DT_t are sustained dummies representing a shift in the intercept and trend respectively occurring at the break time (Bk_y). Model A allows for a one-time change in the intercept while model B considers the impact of a structural break on the trend. Model C is less restrictive and allows for simultaneous shifts in the intercept and trend. This study makes use of model C, hence, hypothesizes a stationary process with one structural break at a break date (Bk_y) and with the dummy specification of:

$DU_t = \{1\ if\ t > Bk_y\ 0\ otherwise$ and $DT_t = \{t - Bk_y\ if\ t > Bk_y\ 0\ otherwise$

The optimal lag determined using the Schwarz-Bayesian Information Criterion (BIC), and the decision rule is to reject the null hypothesis if α is statistically significant.

3.4 Cointegration Tests

The cointegration test has undergone methodological transition as evident in the time series literature (Ahad, Dar, and Imran 2017) - from the traditional and popular Engle & Granger (1987) approach in the late 80s to the Stock & Watson (1988), Phillips & Ouliaris (1990), Johansen (1988, 1991) cointegration test approaches, Boswijk (1994) and the Banerjee et al. (1998) t-test cointegration methodology. The Johansen test was more pronounced and widely adopted. Between the Engel-Granger (EG) and Johanson (JoH), aside from the latter having desirable properties over the former, it also treats test variables as endogenous and allows for more than one cointegrating relationship, albeit its asymptotic properties that result in spurious results with small sample data.

More generally, the four most employed traditional cointegration test approaches (Engle and Granger 1987; Johansen 1988, 1991; Boswijk 1994; Banerjee, Dolado, and Mestre 1998) have failed to provide reliable results for inherently nuisance time-series data that are often characterized with structural breaks resulting from macroeconomic shocks, global financial crises and market volatilities (Pesavento 2004). Further, Pesavento (2004) established the difficulty in obtaining uniform outcomes among the four mentioned techniques. They often produce ambiguous empirical results due to the explanatory power properties (Shahbaz, Nasir, and Roubaud 2018). One approach could result in the acceptance of the null hypothesis of no cointegration while another may reject it. This does not make economic sense (Rafindadi 2016).

3.4.1 Bayer Hanck Cointegration

To overcome the ambiguity problem associated with the four techniques discussed above, Bayer & Hanck (2013) approach combines the strengths and offsets the weaknesses of the four traditional cointegration techniques by combining their p-values using the Fisher (1992) formula as shown below.

$$EG - JoH = -2\left[\ln(P_{EG}) + \ln(P_{JoH})\right] \quad 10$$
$$EG - JoH - Bo - BDM = -2\left[\ln(P_{EG}) + \ln(P_{JoH}) + \ln(P_{Bo}) + \ln(P_{BDM})\right] \quad 11$$

where P_{EG}, P_{JoH}, P_{Bo} and P_{BDM} are the p-values of Engel & Granger, Johansen, Boswijk, and Banerjee et al. respectively. Like many studies (Keho, 2017; Okoro et al., 2021; Shahbaz et al., 2018), the current study uses the Bayer and Hanck approach. The Fisher test for the Bayer-Hanck combined cointegration is conducted under the null hypothesis of no cointegration. According to the model, cointegration exists between the variables when the null hypothesis is rejected. This is true when the estimated Fisher statistics exceed the critical values generated by Bayer and Hanck, and vice versa.

3.4.2 ARDL Bounds Cointegration Test

The Bayer & Hanck (2013) joint cointegration technique is arguably efficient and provides robust empirical results relative to the early traditional approaches. However, it does not take into consideration structural breaks inherent in most time-series data in examining the long-run association between variables (Rafindadi 2016). To resolve this problem, we check the robustness of the results from the Bayer & Hanck (2013) joint cointegration by implementing the Autoregressive Distributed Lag (ARDL) bounds testing approach to cointegration that allows for structural breaks. The ARDL bounds testing approach is specified for the study variables in equation 12-16 below. The ARDL procedure applies to a small sample (Monte Carlo) and is tolerant to $I(0)$ and or $I(1)$ series.

$$\begin{aligned}\Delta\ln E_t = {} & \vartheta_1 + D_E + \delta_1 \ln E_{t-1} + \delta_2 \ln T_{t-1} + \delta_3 \ln I_{t-1} + \delta_4 \ln V_{t-1} + \delta_5 (\ln V_{t-1})^2 \\ & + \sum_{i=1}^{p} \gamma_{1i}\,\Delta\ln E_{t-1} + \sum_{i=0}^{p} \gamma_{2i}\,\Delta\ln T_{t-1} + \sum_{i=0}^{p} \gamma_{3i}\,\Delta\ln I_{t-1} + \sum_{i=0}^{p} \gamma_{4i}\,\Delta\ln V_{t-1} \\ & + \sum_{i=0}^{p} \gamma_{5i}\,\Delta(\ln V_{t-1})^2 + \varepsilon_{1t}\end{aligned} \tag{12}$$

$$\begin{aligned}\Delta\ln T_t = {} & \vartheta_2 + D_T + \delta_6 \ln E_{t-1} + \delta_7 \ln T_{t-1} + \delta_8 \ln I_{t-1} + \delta_9 \ln V_{t-1} + \delta_{10} (\ln V_{t-1})^2 \\ & + \sum_{i=0}^{p} \gamma_{6i}\,\Delta\ln E_{t-1} + \sum_{i=1}^{p} \gamma_{7i}\,\Delta\ln T_{t-1} + \sum_{i=0}^{p} \gamma_{8i}\,\Delta\ln I_{t-1} + \sum_{i=0}^{p} \gamma_{9i}\,\Delta\ln V_{t-1} \\ & + \sum_{i=0}^{p} \gamma_{10i}\,\Delta(\ln V_{t-1})^2 + \varepsilon_{2t}\end{aligned} \tag{13}$$

$$\begin{aligned}\Delta\ln I_t = {} & \vartheta_3 + D_I + \delta_{11} \ln E_{t-1} + \delta_{12} \ln \mathrm{T}_{t-1} + \delta_{13} \ln I_{t-1} + \delta_{14} \ln V_{t-1} + \delta_{15} (\ln V_{t-1})^2 \\ & + \sum_{i=0}^{p} \gamma_{11i}\,\Delta\ln E_{t-1} + \sum_{i=0}^{p} \gamma_{12i}\,\Delta\ln T_{t-1} + \sum_{i=0}^{p} \gamma_{13i}\,\Delta\ln I_{t-1} + \sum_{i=1}^{p} \gamma_{14i}\,\Delta\ln V \\ & + \sum_{i=0}^{p} \gamma_{15i}\,\Delta(\ln V_{t-1})^2 + \varepsilon_{3t}\end{aligned} \tag{14}$$

$$\begin{aligned}\Delta\ln V_t = {} & \vartheta_4 + D_V + \delta_{16} \ln E_{t-1} + \delta_{17} \ln T_{t-1} + \delta_{18} \ln I_{t-1} + \delta_{19} \ln V_{t-1} + \delta_{20} (\ln V_{t-1})^2 \\ & + \sum_{i=0}^{p} \gamma_{16i}\,\Delta\ln E_{t-1} + \sum_{i=0}^{p} \gamma_{17i}\,\Delta\ln T_{t-1} + \sum_{i=0}^{p} \gamma_{18i}\,\Delta\ln I_{t-1} + \sum_{i=1}^{p} \gamma_{19i}\,\Delta\ln V \\ & + \sum_{i=0}^{p} \gamma_{20i}\,\Delta(\ln V_{t-1})^2 + \varepsilon_{4t}\end{aligned} \tag{15}$$

$$\Delta(\ln V_t)^2 = \vartheta_5 + D_{V^2} + \delta_{21}\ln E_{t-1} + \delta_{22}\ln T_{t-1} + \delta_{23}\ln I_{t-1} + \delta_{24}\ln V_{t-1} + \delta_{25}(\ln$$

$$+ \sum_{i=0}^{p}\gamma_{21i}\,\Delta\ln E_{t-1} + \sum_{i=0}^{p}\gamma_{22i}\,\Delta\ln T_{t-1} + \sum_{i=0}^{p}\gamma_{23i}\,\Delta\ln I_{t-1} + \sum_{i=0}^{p}\gamma_{24i}\,\Delta\ln V$$

$$+ \sum_{i=1}^{p}\gamma_{25i}\,\Delta(\ln V_{t-1})^2 + \varepsilon_{5t} \qquad 16$$

where the Δ represents the first difference operator (change parameter), ϑ_i denote the intercepts, D_E, D_T, D_I, D_A, D_{A^2} and D_V are structural break dummy variables, p is the maximum lag length; δ_i and γ_i are the short-run and long-run parameters respectively, and ε_t is the error term. Cointegration is examined under the following arguments. Equation 17 of no cointegration against equation 18 of cointegration.

$$\delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = 0 \qquad 17$$

$$\delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq 0 \qquad 18$$

The testing procedure is based on a joint F-statistic which is compared with the lower and upper critical bounds generated by Pesaran et al. (2001). Cointegration is confirmed if the computed F-statistics is greater than the upper bound. Hence, we reject the null hypothesis. We fail to reject the null hypothesis of no cointegration if the F-statistic falls below the lower bound. If the F-statistic falls between the lower and upper bound, we are unable to confirm whether the variables have a long-run relationship or not. We use the Kripfganz and Schneider (2018) critical values and p-values as a second check for our cointegration results (see Table 7 below). Once cointegration is confirmed among the variables, the next step is to estimate the long-run and short-run parameters.

3.5 Testing the EKC

We implemented the test for EKC after the test for cointegration. For an inverted U-shaped relationship between manufacturing emission and development of the sector, the necessary condition is that $\beta_3 > 0$ and $\beta_4 < 0$, otherwise the EKC is not confirmed. The confirmation of EKC for manufacturing emissions implies that emission initially increases with development in the manufacturing sector, reaches a peak and beyond that level (turning point) emission experiences decline as the sector develops further. We estimated the turning point (lnV^*) by differentiating equation **Error! Reference source not found.** with respect to lnV, equate it to zero and

solve for lnV. We have: $\frac{\delta lnE}{\delta lnV} = 0$ and $lnV^* = -\frac{\beta_3}{2\beta_4}$.

According to Lind & Mehlum (2010), this conventional conditioning of the parameters is not sufficient to confirm or reject an inverted U-shape relationship. They proposed that beyond establishing the appropriate signs and significance of the parameters β_3 and β_4, a sufficient condition requires that the inverted U-shape exists within some interval values - increasing at the left side of the interval (lnV_{min}) and decreases at the right (lnV_{max}) such that;

$$\beta_3 + \beta_4(\ln V_{min}) > 0 > \beta_3 + \beta_4(\ln V_{max}) \text{ for inverted U-shaped relationship} \qquad 19$$

From equation **Error! Reference source not found.**, an inverted U-shaped EKC means that the slope at the left side of the interval [$\beta_3 + \beta_4(lnV_{min})$] must be positive and significant, and the slope at the right end [$\beta_3 + \beta_4(lnV_{max})$] must also be negative and significant. The Lind & Mehlum (2010) formulation also requires that the turning point (lnV^*) falls within the data range. Consistent with the findings of Begum et al. (2015) and Haans et al. (2016), the current study adopts the Lind & Mehlum (2010) test for inverted U-shape due to its robustness.

3.6 Granger Causality

The presence of cointegration confirms the existence of a long-run association among the study variables. It also implies causality in at least one direction, but does not identify the direction of causality (Narayan 2005). This study implements the modified Granger causality test which is the Error-Correction-based Granger causality model to investigate the direction of causality; both in the short-run and the long-run. The rationale of the EC-based granger causality is to augment the conventional Granger with the error-correction term derived from the ARDL cointegration equation. In the test for a causal relationship, Engle and Granger recommends the vector error-correction model (VECM) as the appropriate specification when the series are $I(1)$ and cointegrated. We, therefore, specify the VECM Granger causality approach as follows:

$$(1-L)\begin{bmatrix} \ln E_t \\ \ln T_t \\ \ln I_t \\ \ln V_t \\ (\ln V_t)^2 \end{bmatrix} = \begin{bmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \phi_4 \\ \phi_5 \end{bmatrix} + \begin{bmatrix} D_E \\ D_I \\ D_V \\ D_{V^2} \\ D_T \end{bmatrix} + \sum_{i=1}^{p}(1-L)\begin{bmatrix} \varpi_{11i} & \varpi_{12i} & \varpi_{13i} & \varpi_{14i} & \varpi_{15i} \\ \varpi_{21i} & \varpi_{22i} & \varpi_{23i} & \varpi_{24i} & \varpi_{25i} \\ \varpi_{31i} & \varpi_{32i} & \varpi_{33i} & \iddots & \varpi_{35i} \\ \varpi_{41i} & \varpi_{42i} & \varpi_{43i} & \ddots & \vdots \\ \varpi_{51i} & \varpi_{52i} & \varpi_{53i} & \cdots & \varpi_{55i} \end{bmatrix}$$

$$* \begin{bmatrix} \ln E_{t-1} \\ \ln T_{t-1} \\ \ln I_{t-1} \\ \ln V_{t-1} \\ (\ln V_{t-1})^2 \end{bmatrix} + \begin{bmatrix} \tau_1 \\ \tau_2 \\ 0 \\ \tau_4 \\ \tau_5 \end{bmatrix} [ECT_{t-1}] + \begin{bmatrix} \mu_{1t} \\ \mu_{2t} \\ \mu_{3t} \\ \mu_{4t} \\ \mu_{5t} \end{bmatrix} \qquad 20$$

where L denotes the lag operator, $(1-L)$ denotes the first difference operator, ECT_{t-1} is the lagged error correction term, and $\mu_{it}(i = 1, 2, ..., 5)$ are the error terms which are iid with zero mean and constant variance. The selection of the appropriate lag length (p) was based on the Akaike Information Criteria (AIC). We used this model to ascertain the long-run and short-run causal relationship among the variables. The long-run causal relationship is identified by the significance of the t-statistic associated with the lagged error correction term (ECT_{t-1}) while the significance of the chi-square associated with the first differenced lagged regressors implies short-run Granger causality.

4. Empirical Results

The descriptive statistics and the correlation matrix of the study variables are reported in Table *1* below. Manufacturing emissions has a weak positive relationship with manufacturing trade, but negatively (strongly) correlated with each of the other variables. Manufacturing FDI is negatively correlated with trade intensity indicating a weak and deteriorating link between investment in the sector and the sector's international competitiveness. FDI, manufacturing output and growth of manufacturing output show positive correlation pairs.

Table 1: Descriptive Statistics and Correlation Matrix

	lnE_t	lnT_t	lnI_t	lnV_t	(lnV_t)^2
Mean	6.5962	-0.6690	2.0491	18.4108	341.5026
Median	6.6063	-0.9086	1.7183	17.8472	318.5210
Standard Deviation	0.5342	0.5796	1.6291	1.6192	61.3722
Minimum	5.6576	-1.5113	-0.3437	16.6357	276.7480
Maximum	7.5608	0.7711	5.0007	22.4710	504.9458
Skewness	0.0930	0.6620	0.3187	0.6579	0.7806
Kurtosis	1.9946	2.6675	2.0515	2.3735	2.6814
Number of observations	35	35	35	35	35
lnE_t	1.0000				
lnT_t	0.0544	1.0000			
lnI_t	-0.8589	-0.1172	1.0000		
lnV_t	-0.8197	0.3846	0.7529	1.0000	
(lnV_t)^2	-0.8118	0.3939	0.7445	0.9992	1.0000

Table 2 below shows the results for the conventional unit root tests, ADF (Dickey and Fuller 1981) and PP (Phillips and Perron 1988). Both tests show that the series are $I(0)$ and $I(1)$. Our time series are susceptible to structural breaks which the conventional approaches do not account for. To help promote comprehensive and green policies for energy, trade, and investment in the manufacturing sector, information about the structural breaks is paramount. We conducted the Zivot & Andrews's (2002) single break unit root test (see Table 3 below) which confirmed the results from the conventional test. The series were further subjected to the Clemente-Montanes-Reyes (Clemente, Montañés, and Reyes 1998) multiple break unit root test due to the period under consideration (where multiple historical breaks are expected), especially owing to the manufacturing sector policies, and trade and foreign investment policies over the years. Table 4 below shows the result for the Clemente-Montanes-Reyes IO model test which captures any gradual shifts in the series. It is evident that all the variables according to the Clemente-Montanes-Reyes become stationary after first difference, indicating that all the series are I(1).

Table 2: Conventional unit root test - ADF and PP

Variable	**ADF**				**PP**			
	No-Trend		Trend		No-Trend		Trend	
	d(0)	d(1)	d(0)	d(1)	d(0)	d(1)	d(0)	d(1)
lnE_t	-0.309	-7.706 ^{a}	-3.715 ^{b}	-7.966 ^{a}	0.167	-7.861 ^{a}	-3.590 ^{b}	-8.332 ^{a}
lnT_t	-1.549	-4.933 ^{a}	-1.381	-5.655 ^{a}	-1.650	-4.958 ^{a}	-1.286	-5.736 ^{a}
lnI_t	-1.150	-5.266 ^{a}	-2.481	-5.193 ^{a}	-1.181	-5.247 ^{a}	-2.525	-5.169 ^{a}
lnV_t	-3.250 ^{b}	-4.838 ^{a}	-1.729	-5.061 ^{a}	-3.096 ^{b}	-4.882 ^{a}	-1.878	-5.078 ^{a}
(lnV_t)^2	-3.649 ^{b}	-4.795 ^{a}	-2.155	-4.936 ^{a}	-3.404 ^{b}	-4.926 ^{a}	-2.284	-5.014 ^{a}

^{a} & ^{b} indicate statistically significant at 1% & 5% respectively.

Table 3: Zivot-Andrews unit root test (trend & intercept) with structural break

Variable	Level		1st Difference	
	t-Statistic	Break year	t-Statistic	Break year
lnE_t	-4.972(0) [c]	1985	-8.554(1) [a]	1998
lnT_t	-2.706(0)	1986	-5.897(0) [a]	2006
lnI_t	-3.553(1)	1993	-6.361(0) [a]	1995
lnV_t	-4.914(0) [c]	2000	-6.420(0) [a]	1986
(lnV_t)^2	-5.287(0) [b]	2000	-6.708(2) [a]	2004

[a], [b], & [c] denote statistically significant at 1%, 5% and 10%

Table 4: Clemente-Montanez-Reyes Unit Root Test (IO Model) with Multiple Breaks

Variable	Level			1st Difference		
	t-Statistic	Bk$_y$ 1	Bk$_y$ 2	t-Statistic	Bk$_y$ 1	Bk$_y$ 2
lnE_t	-2.826(2)	1992	2002	-8.032(1) [b]	1987	2011
lnT_t	-3.384(8)	1982	2004	-8.400(1) [b]	1986	2005
lnI_t	-4.133(0)	1991	2005	-6.437(1) [b]	1985	1996
lnV_t	-1.873(7)	1984	1992	-5.627(1) [b]	1983	2005
(lnV_t)^2	-1.852(7)	1984	1992	-5.883(1) [b]	1983	2005

[b] denotes statistical significance at 5%.
Critical value of rho -1 (5%) = -5.490

This level of stationarity would warrant a vector error correction specification in the presence of cointegration. Also, most of the breaks occur in the 1980s, particularly in the first break (Bk$_y$ 1). The second breaks occur most in 2005. The first break can be mostly explained by the many national issues during the 1980s. The year 1981 marked the beginning of Ghana's most severe drought which lasted till 1983 (Dei 1988; Tan and Rockmore 2019). This was compounded with harmattan conditions and severe economic and political turmoil (Tan and Rockmore 2019). The prolonged drought led to reduction in agricultural production and subsequently famine. This necessitated the economic recovery program (ERP) by the Government of Ghana in 1983 aimed at economic stabilization and structural adjustment (Kusi 1991). This has grave structural implications for the economy including reduction in exports, investment, and sector activities especially agricultural and manufacturing.

4.1 Cointegration results

Table 5 below shows the Bayer & Hanck (2013) cointegration results for the different models (1, 2, 3, 4, and 5). Comparing the F-Statistics for EG-JoH, and EG-JoH-Bo-BDM to their respective critical values at a 5% level of significance, we fail to reject the null of no cointegration for all 5 models. Hence all 5 models, according to the Bayer-Hanck approach, exhibit a long-run relationship. We further conducted the ARDL bounds approach to test the robustness of the results generated by the Bayer and Hanck approach, and to examine the long run association in the presence of structural break since our data is susceptible of structural breaks.

Table 5: Bayer and Hanck Cointegration Test Results

Model Specification		Fisher Statistics		Cointeg.
		EG-JOH	EG-JOH-BO-BDM	
Model 1	$\ln E_t = f[\ln T_t, \ln I_t, \ln V_t, (\ln V_t)^2]$	55.3847 [a]	126.2949 [a]	Yes
Model 2	$\ln T_t = f[\ln E_t, \ln I_t, \ln V_t, (\ln V_t)^2]$	56.1979 [a]	59.1765 [a]	Yes
Model 3	$\ln I_t = f[\ln E_t, \ln T_t, \ln V_t, (\ln V_t)^2]$	55.7449 [a]	112.2246 [a]	Yes
Model 4	$\ln V_t = f[\ln E_t, \ln T_t, \ln I_t, (\ln V_t)^2]$	55.3211 [a]	165.8452 [a]	Yes
Model 5	$(\ln V_t)^2 = f[\ln E_t, \ln T_t, \ln I_t, \ln V_t]$	55.3830 [a]	165.9071 [a]	Yes
1% significance level		15.973	30.836	

[a] denote statistical significance at 1%

The results of the ARDL bounds cointegration test are reported in Table 6 below. Contrary to the Bayer & Hanck (2013) results, the ARDL reports cointegration for 4 out of the 5 models. The F-statistic is greater than the Narayan (2005) critical values for models 1, 2, 4, and 5, indicating 4 cointegrating relationships. For model 3, however, the computed F-statistics is less than the 1% lower critical value but falls between the respective Narayan (2005) critical values at 5% and 10%. This implies inconclusive cointegration. Thus, at 5%, the decision is inconclusive for model 3. This result of the ARDL bounds test is cross-examined using the Kripfganz & Schneider (2018) critical values and their respective p-values reported in Table 7 below. Similar to Narayan (2005), the test statistic (F-stats) is less than the lower bound (LB) of the Kripfganz & Schneider (2018) critical value at 1% as well as the 5% implying the absence of cointegration. On the contrary, we could not make conclusions at 10% critical values since the F statistic fall between the lower bound (LB) and upper bound (UB) critical values.

Table 6: ARDL Bounds test for Cointegration

Model Specification	Model lag	R2	Adj. R2	F-statistic	Cointeg.
$\ln E_t = f[\ln I_t, \ln A_t, (\ln A_t)^2, \ln T_t]$	(1,2,0,2,1)	0.5939	0.4092	5.683 [a]	Yes
$\ln T_t = f[\ln E_t, \ln I_t, \ln A_t, (\ln A_t)^2]$	(1,1,0,2,2)	0.8461	0.7762	12.766 [a]	Yes
$\ln I_t = f[\ln E_t, \ln T_t, \ln A_t, (\ln A_t)^2]$	(2,0,1,1,1)	0.5767	0.4110	3.264	Inconclusive
$\ln A_t = f[\ln E_t, \ln T_t, \ln I_t, (\ln A_t)^2]$	(2,0,2,0,1)	0.9983	0.9976	8.600 [a]	Yes
$(\ln A_t)^2 = f[\ln E_t, \ln T_t, \ln I_t, \ln A_t]$	(1,0,2,0,2)	0.9983	0.9977	8.936 [a]	Yes
Critical Values		$I(0)$	$I(1)$		
1% significance level		3.74	5.06		
5% significance level		2.86	4.01		

[a] denotes significance at 1%

Table 7: Kripfganz and Schneider (2018) critical values and approximate p-values

	Model 1		Model 2		Model 3		Model 4		Model 5	
	LB	UB	LB	UB	LB	UB	LB	UB	LB	UB
1%	4.870	6.930	4.870	6.930	4.853	6.852	4.709	6.852	4.853	6.852

5%	3.324	4.881	3.324	4.881	3.327	4.847	3.327	4.847	3.327	4.847
10%	2.701	4.049	2.701	4.049	2.709	4.029	2.709	4.029	2.709	4.029
p-values	0.005	0.026	0.000	0.000	**0.054**	**0.192**	0.000a	0.003	0.000	0.002

The evidence of cointegration suggests that the series turn to move together in the long run, hence, we estimated the long-run and short-run impacts of trade intensity, FDI, and manufacturing output on manufacturing carbon dioxide emissions. The long-run and short-run ARDL results are reported in Table 8 and Table 9 below respectively. Similar to Adusah-Poku (2016) who found trade openness to positively impact emissions for Sub Saharan Africa (SSA) and Abokyi et al. (2021) for Ghana, the current study shows a positive relationship between manufacturing trade and emissions at 10% significance level in the long-run. A 1% increase in trade intensity increases emissions by 0.2745%. As a proxy for trade openness in the manufacturing sector, the manufacturing trade intensity measures the integration of the sector with the world economy relative to other sectors. Because Ghana is a net importer of manufacturing products, especially electronic wastes (Twerefou, Adusah-Poku, and Bekoe 2016) such as cars, television, and hundreds of other consumer non-durables, increases in trade intensity is import-driven. Unlike previous studies (Twerefou et al., 2016) that attempt to give export-oriented intuition to this effect, this study argues that the environmental impact of trade intensity is better conveyed in an import-oriented explanation since Ghana like most developing countries are net-importers. Further, Ghana for decades has been a victim of dumping, hence, the result for trade intensity is not surprising. Contrary to this result, Boateng (2020), Kwakwa & Alhassan (2018), Kwakwa et al. (2019) found reducing effect of trade on CO_2 emissions.

FDI into manufacturing show a negative but insignificant effect on the sector's emissions of CO_2. For Ghana's manufacturing sector and its emissions, our study indicates that although FDI could have reducing effect on CO2 emission, this effect cannot be statistically concluded on, both in the short run and the long run. A percentage increase in FDI could reduce emission by 0.02 to 0.03 percentage, albeit insignificant. Hence, we cannot confirm the hallo or haven hypothesis for FDI and CO_2 emissions. This findings is in consonance with Al-mulali & Tang (2013) but contradicts other studies (Sun et al. 2021; Zhao et al. 2021) that found significant relationship between FDI and emissions.

Real manufacturing output impacts positively and negatively on CO_2 emission in the sector. At a 5% level of significance, a 1% increase in manufacturing output increases emissions by 2.6284%. This result is consistent with the intuition that emission is a by-product of production activities. In General, we found an inverted U-shaped relationship between manufacturing output and CO_2 emission. The respective positive and negative signs of the coefficients of $\ln V_t$ and $(\ln V_t)^2$ imply that at the initial stages of development of the manufacturing sub-sector, a percentage increase in manufacturing output results in an increase in the sector's emission of CO2 by 2.6284% while at higher stages of development (indicated by the squared term of manufacturing output), CO_2 emissions declines by 0.0814%. In other words, the sector's emission of CO_2 increases at the early phase of sector development and beyond some point experiences decline, albeit at a relatively slower rate. This finding confirms the necessary conditions for EKC. The magnitude of the emission decrease over the development path of the manufacturing sub-sector explains the slow rate of environmentally friendly technologies applied in the sector. In effect, the scale effect from the sector development leading to increases in emission far outweighs the emission-reduction technique effect. The relative rate of increase and decrease in CO_2 emissions is an indication that the shape of the sector's EKC curve for the sector peaks early (See Figure 1 below). The finding of an inverted U-shaped of CO_2 emission for the manufacturing sub-sector confirms the findings of previous studies on Ghana (Aboagye 2017; Kwakwa and Alhassan 2018; Kwakwa, Alhassan, and Adu 2019) but in sharp contrast to other studies on Ghana (Aboagye, 2017; Sarkodie & Strezov, 2018; Twerefou et al., 2016).

Table 8: Long-run results for ARDL model (1,2,0,2,1)

Dependent variable = lnE_t			
Variables	Coeff.	Std. Error	t-stat
lnT_t	0.2745 ^{c}	0.1535	1.79
lnI_t	-0.0343	0.0698	-0.49
lnV_t	2.6284 ^{b}	1.299	2.02
(lnV_t)^2	-0.0814 ^{b}	0.0362	-2.25

^{b} & ^{c} denotes significance at 5% and 10% respectively

Table 9: Short-run results for ARDL model (1,2,0,2,1)

Dependent variable = lnE_t			
Variables	Coeff.	Std. Error	t-stat
Constant	-8.3749	1.4534	-5.7623
Δ lnT_t	-0.2893 ^{c}	0.1422	-2.03
Δ lnI_t	-0.0209	0.0424	-0.49
Δ lnV_t	2.6896 ^{b}	0.0896	2.90
Δ (lnV_t)^2	-0.0705 ^{b}	0.0338	-2.09
ECT_{t-1}	-0.6089 ^{a}	0.1739	-3.50

^{b} & ^{c} denotes significance at 5% and 10% respectively

Table 10: Diagnostic tests

		Chi-sq.	Prob.
Arch		0.0157	0.9003
Serial		3.525	0.1717
Hetero		33	0.4180
Norm		0.6297	0.7299
Ramey RESET	2.08		0.1372

Table 9 above shows the outcomes for the short-run analysis. Firstly, the coefficient of the error correction term is -0.6098 and significant at 1%. This confirms that the variables are cointegrated and move towards long-run stability such that any short-run deviations in the model are eventually corrected. The speed of adjustment of 0.6098 suggests that approximately 61% of short-run disturbances are corrected each year. The implication is that it takes roughly a year and half for deviations to be restored to equilibrium. The directional effect of manufacturing output on CO_2 emission is consistent with the long-run impact and it is statistically significant at 5%. The EKC is again confirmed in the short run. Contrary to long-run results, trade intensity shows a negative impact on manufacturing emissions in the short run.

This study's findings differ (from previous findings/studies) for several reasons. First, unlike previous studies, it focuses on the manufacturing sub-sector and its emission of CO_2. Second, the model adopted for this study is robust and accounts for the transition from manufacturing activities to emission through the manufacturing output-emission parameter. Moreso, our model explicitly accounts for the non-linearity of the production-CO_2 emission relationship.

4.2 Proof of EKC

The second-order test for inverted U shape according to the Lind & Mehlum (2010) propositions is reported in Table 11 below. The slopes of the lower and upper bounds are significant at 10% and 1% respectively. They exhibit the appropriate slope signs of positive and negative for the respective lower and upper bounds which meet the sufficient condition for inverse U shape. The turning point of lnV_t is 17.861 (equivalent to 57,139,145 Ghana cedis in real manufacturing output) must fall within the data range to satisfy the Lind & Mehlum (2010) turning point condition for inverse U shape. The data range for lnV_t is 16.6357 to 22.4710 (see Table 1 above) equivalent to 16,780,029 to 5,741,578,446 Ghana cedis in real manufacturing output. Clearly, the turning point condition is met. The curve peaks early (at the left side of the data range) which confirms the net scale effect of EKC mentioned earlier. Further, the overall test of presence of an inverse U shape is significant at 10% indicating a rejection of the null of monotone or U shape. This is confirmed in Figure *1* which shows a scatter plot of log of real manufacturing output (lnV_t) against the log of manufacturing emission of CO_2 (lnE_t) which also confirms the turning point condition.

Table 11: Lind and Mehlum second-order test for inverted U-shape

	H1: Inverse U shape		
	H0: Monotone or U shape		
	Lower bound (LB)	Upper bound (UB)	Overall
Slope	0.2943 ^{c}	-1.1073 ^{a}	
t-value	1.6007	-3.4759	1.60
prob. Value	0.0619	0.0011	0.0619
Extreme point of lnV_t = 17.861			

^{a} & ^{c} denotes significance at 1% and 10% respectively

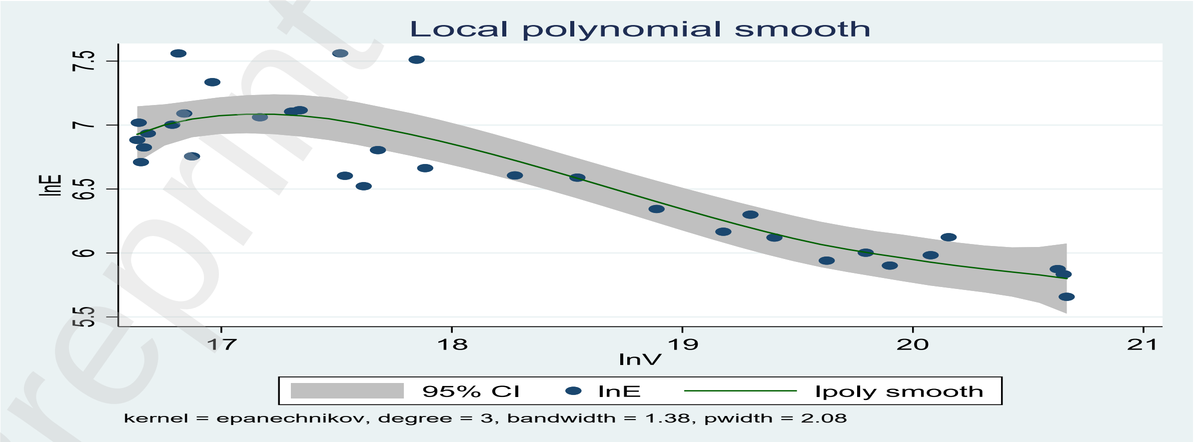

Figure 1: Inverted U-shape: Manufacturing emission of CO_2 and manufacturing output relationship

4.3 Short-run and Long-run Granger Causality: VECM

The VEC-based Granger causality test results are presented in Table 12 below which reports the t-statistics for the short-run granger causality among the variables and their respective levels of significance. The bounds test results show evidence of a long-run association among the study variables for all the models except model 3 (when the log of FDI is the dependent variable). For models 1, 2, 4, and 5 where cointegration is confirmed, we constructed an error correction augmented Granger causality test by including a lagged error-correction term following Narayan & Smyth (2004). Unlike Narayan & Smyth (2004), this study makes use of the probability values of the chi-square statistics in determining short-run causality.

The coefficient of the lagged error correction term for model 1 is significant at 1% and has the expected negative sign. This means that almost half of any short-run deviations in the model are corrected in a year. This result confirms the bounds test outcome for model 1. For model 2 however, the coefficient of the lagged error correction term is significant at 10% albeit with a positive sign. This suggests that short-run deviations do not move towards long-run equilibrium. In the short run, the t-statistics indicate a unidirectional causality in model 2. That is, at 5%, there is Granger causality running from manufacturing emissions (lnE_t) to trade intensity (lnT_t), 1% unidirectional Granger causality each from manufacturing output (lnV_t) and manufacturing output growth ((lnV_t)^2) to manufacturing trade intensity (lnT_t).

Table 12: Long-run and short-run ECM-based Granger causality test results

	Dependent variables				
	Δ lnE_t	Δ lnT_t	Δ lnI_t	Δ lnV_t	Δ (lnV_t)^2
Short run					
Δ lnE_t	-	4.81 [b]	1.19	0.37	0.60
Δ lnT_t	0.64	-	0.33	0.01	0.03
Δ lnI_t	0.19	0.18	-	1.43	1.61
Δ lnV_t	0.99	7.61 [a]	0.01	-	-
Δ (lnV_t)^2	0.84	7.72 [a]	0.00	-	-
Long-run					
Coeff. of ECT_{t-1}	-0.4787 [a]	0.4358 [c]	-	-	-

[a] & [c] denotes significance at 1% and 10% respectively

4.4 Impulse response and variance decomposition functions

Figure *2* below shows the impulse response of the study variables in a system of 4 equations. It shows that CO_2 emission responds positively to shocks in trade intensity. It increases up to the 12th period when it becomes stable over time. The impact of a shock in FDI on CO_2 emissions is negative and a mirror of the response to shocks in trade intensity. The response of CO_2 emissions to shocks in manufacturing output is consistent with the outcome of the bound test and the Lind and Mehlum test for inverse U shape. This confirms that the relationship peaks early and at the left-side of the output-emission path. Trade intensity responds positively to impulses in CO_2 emissions exhibiting an inverse U shape in the first 4 period; but reacts negatively to shocks in FDI - no response to shocks until after the 4th year when it declines. At the earlier stages, trade intensity declines with a shock in manufacturing output. It increases and decreases each year up to the 5th period when it reduces. FDI responds to CO_2 emission and trade intensity with an initial decrease, increasing after the second year and showing a movement towards the steady state. Similarly, FDI initially declines with a shock in manufacturing output but increases in the second year and assumes an inverse U shape relationship towards steady state equilibrium. A one standard deviation shock to CO_2 emission and FDI increases manufacturing output and decline after the third period. For a shock in trade intensity, manufacturing output initially decreases and increases after the first year and begins the cycle of increase and decrease every period. The variance decomposition effect is presented in Table 13 below. It is evident from the table that the short run forecast error variance in CO_2 emissions and trade intensity are explained by their own innovations.

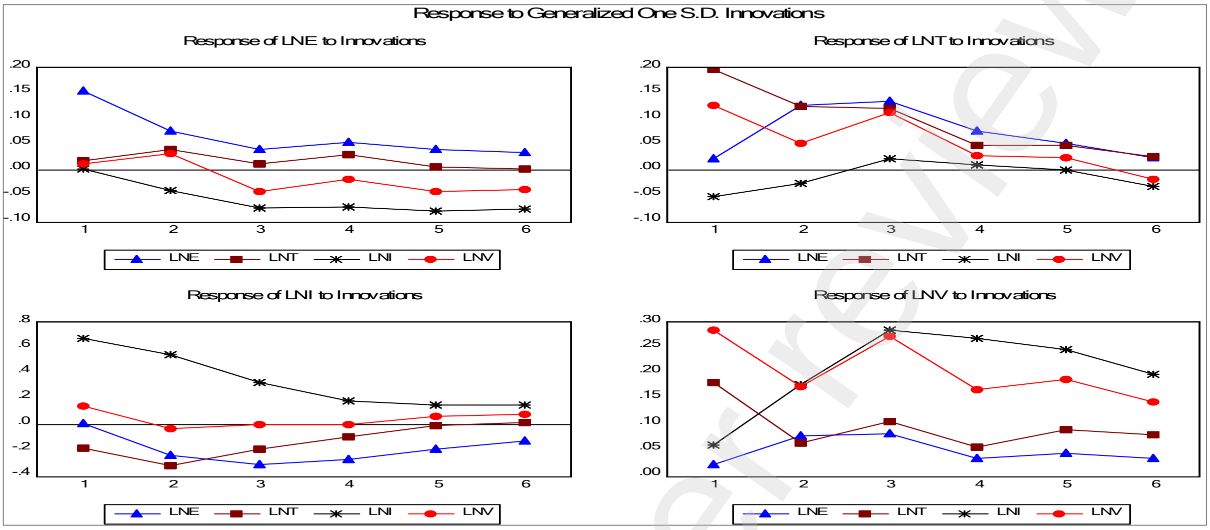

Figure 2: Generalized Impulse Response ($\ln E_t$ $\ln T_t$ $\ln I_t$ $\ln V_t$ $(\ln V_t)^2$)

Table 13: Decomposition of variance (Percentage of forecast variance explained by innovations)

	Forecast Horizon	Forecast Standard Error	Variance decomposition (percentage points)				
			$\ln E_t$	$\ln T_t$	$\ln I_t$	$\ln V_t$	$(\ln V_t)^2$
$\ln E_t$							
	1	0.134	100	0	0	0	0
	4	0.196	86.348	0.424	9.013	2.826	1.389
	8	0.246	83.674	0.584	11.204	3.538	1.00
	12	0.287	80.147	0.565	13.957	4.576	0.756
$\ln T_t$							
	1	0.221	0.815	99.185	0	0	0
	4	0.454	1.197	94.437	0.444	3.693	0.229
	8	0.678	0.731	89.728	1.012	8.337	0.191
	12	0.865	0.797	85.961	1.898	11.163	0.181
$\ln I_t$							
	1	0.658	1.696	0.244	98.060	0	0
	4	1.375	7.700	21.743	67.654	0.601	2.302
	8	1.890	6.822	28.852	61.493	0.367	2.467
	12	2.323	7.026	30.985	59.190	0.283	2.516
$\ln V_t$							
	1	0.332	3.954	54.072	13.636	28.338	0
	4	0.806	9.097	33.723	39.088	17.916	0.176

	8	1.095	11.158	33.796	39.963	14.981	0.102
	12	1.325	11.379	34.369	40.467	13.709	0.076
$(\ln V_t)^2$							
	1	11.544	3.996	51.984	15.722	28.232	0.067
	4	28.619	8.362	31.395	43.225	16.863	0.155
	8	38.484	10.222	32.290	43.820	13.569	0.100
	12	46.458	10.307	33.290	44.240	12.093	0.070
	16	53.071	10.243	33.991	44.391	11.321	0.054

5. Conclusion and Policy Implication

Since independence, Ghana has focused on increasing manufacturing activities to promote industrialization and overall economic transformation. Despite some initial difficulties, the sector has recently made significant positive strides, even amid the global disruptions resulting from the COVID-19 pandemic. The manufacturing sector also attracts most FDI inflows on average and constitutes one of the most traded subsectors on the international market. However, there has been limited efforts to study the impact of manufacturing activities on carbon dioxide emissions for feasible green interventions in Ghana. In this article, we focused our attention on how manufacturing sector activities and its openness to trade and FDI impacts on carbon dioxide emissions in Ghana. Specifically, we investigate the short run and long run effects of FDI, trade, and manufacturing production on CO_2 emissions. We also test the EKC hypothesis for growth of manufacturing and its emission of CO_2. To achieve this, we carefully examined the time series properties of the data by testing for unit root using different test approaches. We then used the Bayer & Hanck (2013) cointegration approach to examine the short run and long run relationship and used the ARDL bounds testing approach as a robust test.

The results, both for the short run and long run analyses, revealed that there is a positive relationship between manufacturing trade and CO_2 emissions in Ghana. Since Ghana, like many other developing countries are net importers of manufacturing goods, such as cars, household appliances, spare parts, and many other nondurable consumer goods, we follow Twerefou et al. (2016) to conclude that the increase in trade intensity is imports driven. Since Ghana has been a victim of dumping of manufacturing goods in recent times, the result is critical in the formulation of anti-dumping policies which could also improve environmental quality beside improving local green production of manufactured goods and merchandised trade balance. The results also implied that there is a positive relationship between manufacturing production and CO_2 emissions in Ghana. However, further analyses revealed that there is an inverted U relationship between them. That is, at the initial stage of development in the manufacturing sector, production increased CO_2 emissions. However, further development in the sector, through the implementation of more environmentally friendly technology, leads to reduction in CO_2 emissions. Further test confirmed the existence of EKC. Finally, we found that there is no significant relationship between FDI inflows to the manufacturing sector and its CO_2 emissions.

The findings of this article differ from those of earlier studies in the sense that it focuses on the manufacturing sub sector and explicitly accounts for the nonlinearity of the manufacturing production-CO_2 emissions relationship. From policy formulation point of view, this article has highlighted the need for trade and industrial policies that prevent dumping of manufacturing good on Ghana while promoting local production of environmentally friendly manufacturing goods.

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Appendix: Graph of Recursive Estimates

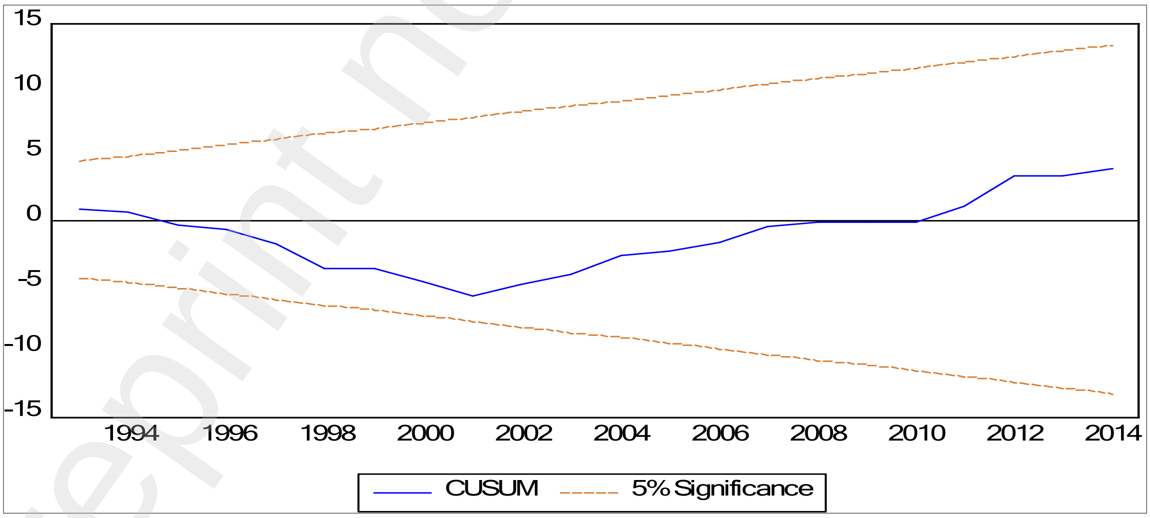

Figure A.1
CUSUM Plot

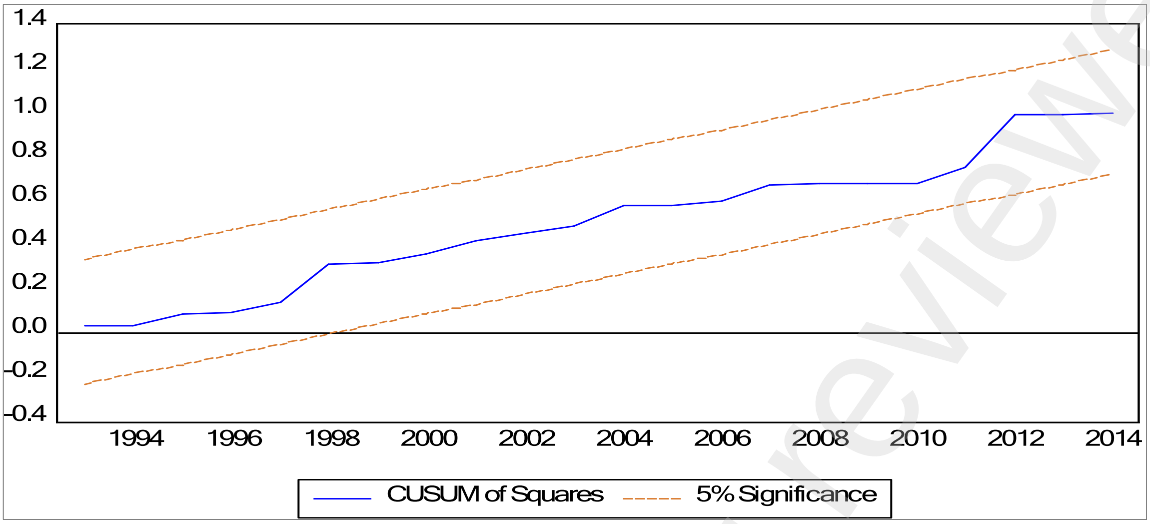

Figure A.2
Plot of CUSUM Squares

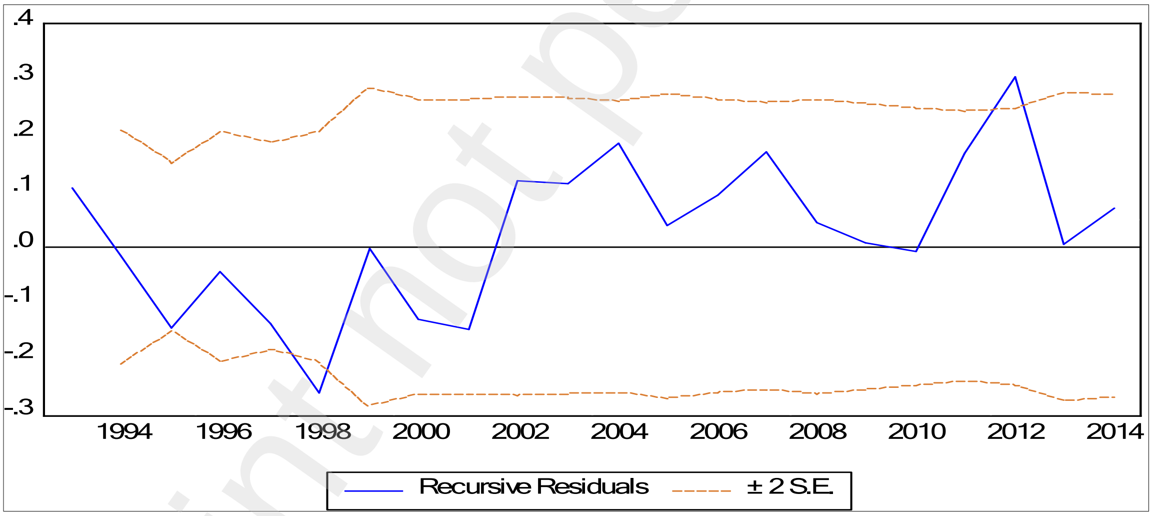

Figure A.3
Plot of Recursive Residuals

The Effect of Manufacturing activities and Economic Openness on CO_2 Emissions in Ghana: An Autoregressive Distributed Lagged Bounds Approach [*]

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