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Examining the relationship between greenhouse gas emission and economic development. Evidence from the manufacturing sector of Ghana

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Abstract

Using Ghana's manufacturing sector as a case study, this paper explores the complex relationship between greenhouse gas (GHG) emissions and economic development
The results demonstrate a strong positive relationship between population size and GHG emissions, suggesting that rising population densities fuel increased demand for industrial goods and services and, in turn, drive up emissions. Nonetheless, it was discovered that a number of economic factors, including GDP, manufacturing value-added, and foreign direct investment, had non-significant coefficients, indicating that their impact on GHG emissions in Ghana's environment may not be as great.

Even if some of the economic components are not significant, the model fits the data well, indicating that the factors that are included account for a sizable percentage of the variability in GHG emissions. This emphasizes how important economic factors are in determining emission patterns in Ghana's industrial environment. The study also emphasizes how intricate the connection is between Ghana's manufacturing sector's economic growth and greenhouse gas emissions. It emphasizes how important it is to take population growth and other economic factors into account in order to fully solve emissions concerns.

The analysis provides relevant policy implications to inform focused policy initiatives geared at reducing GHG emissions and promoting sustainable economic growth.
Overall, this study offers insightful information about the complex relationship between economic growth and greenhouse gas emissions in Ghana's manufacturing sector, which paves the way for well-informed policymaking and well-timed interventions to advance both environmental sustainability and economic prosperity.

Keywords: Greenhouse gas emissions, economic development, manufacturing sector

1. Introduction

Due to globalization, environmental concerns have been thoroughly deliberated and discussed in most international fora (Tukker et al., 2018). Greenhouse gases were naturally an essential presence for life in their appropriate measures (Ansuategi & Escapa 2002), However human activities in the past century have been emitting GHS at an alarming rate in geologic time (Shah et al., 2024). This phenomenon has resulted in environmental problems whose intensity has required disciplines such as sociology which hitherto, did not explore physical environment as a significant subject, now deems it appropriate to explore probably because the relationship between the physical environment and human activities have become very visible (Dunlap & Catton, 1979). Beinart 2000 and Owusu, 2022, expressed concerns that, the severity of the environment challenges is so pervasive in that it has the potential to adversely impact production in Ivory Coast and Ghana in the area of cocoa production. Although UNEP cleared Ghana as having a relatively cleaner atmosphere in 2013. The severity of the situation has led to the estimate that the cost of environmental pollution from the manufacturing sector of Ghana is about 10% although the sectors contribution to GDP is only about 1.7% (CPA, 2011; UNEP, 2013).

Ghana's manufacturing sector has experienced significant growth in recent years, driven by factors such as foreign direct investment, trade liberalization, and government policies aimed at promoting industrialization (Appiah et al.,2023). While this growth has contributed to the country's economic development, it has also led to an increase in greenhouse gas (GHG) emissions, particularly carbon dioxide (CO_2) (Sarkodie & Strezov, 2019). The manufacturing industry is a major source of GHG emissions due to its heavy reliance on fossil fuels for energy and the production processes involved (UNEP, 2013) (Oteng-Abayie et al., 2022; Gyimah et al.,2023).

Previous studies have attempted to link the relationship between economic growth and environmental degradation to the Environmental Kuznets Curve (EKC) hypothesis, which suggests that in the initial stages of economic development, environmental degradation increases due to the prioritization of growth over environmental concerns. However, as economies reach a certain level of development, the trend reverses, and environmental quality improves due to increased awareness, technological advancements, and stricter regulations (Bozkurt & Akan,2014). Some researchers have argued that, the level of growth needed to warrant the reverse trend of environmental pollution is very high and, in some cases, unattainable in the face of the persisting pollution and the international nature of its implications such as global warming and its intergenerational consequences, as such meaningful EKC do not exist for greenhouse gas emission in particular. It is therefore imperative to give greenhouse gas emission a serious attention now rather than the expectation of a future reversal of impact (Tuckett, 2021).

In the case of Ghana at a sectorial level, there is a need to understand the dynamics between the manufacturing sector's growth and its impact on GHG emissions. Specifically, the following problems need to be addressed, the absence of all-inclusive and reliable data on GHG emissions from the manufacturing sector in Ghana, making it very difficult to precisely assess the sector's contribution to the country's overall emissions in order to design sector specific solutions to mitigate such problems. Manufacturing industries in Ghana may still rely on outdated and inefficient technologies, leading to higher energy consumption and GHG emissions. The adoption of cleaner and more efficient technologies has been limited due to various factors, including cost, lack of awareness, and inadequate incentives (Ohene et al., 2023). There is a need to strike a balance between promoting economic growth through the expansion of the manufacturing sector and mitigating the sector's environmental impact, particularly in terms of GHG emissions (Raihan, 2024). Ghana's regulatory framework for addressing GHG emissions in the manufacturing sector may be inadequate or poorly enforced, leading to a lack of incentives for industries to adopt sustainable practices and invest in emission reduction measures.

The research aims to investigate the relationship between GHG emissions and the growth of the manufacturing sector in Ghana. Specifically, it will examine the following aspects: Trends in GHG emissions from the manufacturing sector over time and their contribution to Ghana's overall emissions, the impact of manufacturing sector growth on GHG emissions, considering factors such as energy consumption, production processes, and technological advancements, the potential for decoupling economic growth from GHG emissions in the manufacturing sector through the adoption of cleaner technologies, energy efficiency measures, and renewable energy sources, the role of government policies, regulations, and incentives in promoting sustainable practices within the manufacturing sector and mitigating GHG emissions.

Achievement of sustainable development goals is premised on fixing these crucial problems and align with international commitments to combat climate change. By understanding the relationship between GHG emissions and the growth of the manufacturing sector, policymakers and stakeholders can develop informed strategies to decouple economic growth from environmental degradation, promote the adoption of cleaner technologies, and create a regulatory environment that incentivizes sustainable practices within the manufacturing industry.

2. Literature Review

Numerous studies have examined the relationship between greenhouse gas (GHG) emissions and economic development, with a focus on the Environmental Kuznets Curve (EKC) hypothesis. This hypothesis suggests that during the initial stages of economic growth, environmental degradation increases due to the prioritization of growth over environmental concerns. However, as economies progress, there is a reversal of this trend, leading to improved environmental quality due to increased awareness, technological advancements, and stricter regulations (Bour et al., 2022).

In the specific context of Ghana, Appiah (2022) found a positive correlation between economic growth and CO2 emissions, indicating that emissions tend to increase as the economy grows (Oteng-Abayie et al., 2022). However, the study also noted that Ghana has experienced relatively low levels of emissions compared to advanced countries, which could be attributed to the implementation of carbon mitigation policies and lower emission factors

2.1 Manufacturing Sector and GHG Emissions

The manufacturing sector significantly contributes to greenhouse gas (GHG) emissions due to its heavy reliance on fossil fuels for energy and production processes (Qian et al., 2024). These practices have led to widespread environmental problems, including the discharge of organic and inorganic wastes into water bodies, resulting in adverse effects on both human health and the environment (Bour et al., 2019). In Ghana, a 2013 report by the United Nations Environment Programme (UNEP) identified the industrial sector, particularly the manufacturing subsector, as the primary contributor to GHG emissions in the country (Bour et al., 2019). Obiuto et al.,2024 also stressed the importance of controlling and managing wastes from production sites to safeguard local ecology and health. Various studies have investigated the specific factors driving GHG emissions within the manufacturing sector. Oteng-Abayie et al. (2022) conducted an analysis of energy consumption patterns across sectors such as industry, agriculture, residential, and transportation to understand the factors influencing carbon dioxide emissions in Ghana. Their research revealed that the transportation sector was the largest contributor, influenced by economic prosperity and population growth.

Oteng-Abayie et al. (2022) undertook an analysis of the decoupling status of CO2 emissions from economic growth in Ghana. Their findings from the period between 1990 and 2018 indicated weak decoupling, with CO2 emissions growing at a slower rate than economic growth. This trend was attributed to the implementation of carbon mitigation policies and lower emission factors observed in Ghana compared to more developed nations. Overall, these studies underscore the critical role of the manufacturing sector in GHG emissions and highlight the importance of adopting sustainable practices and policies to mitigate environmental impacts and promote economic growth in a more environmentally friendly manner.

2.2 Regulatory Framework and Policies

Numerous studies have underscored the critical role of a robust regulatory framework and effective policies in addressing greenhouse gas (GHG) emissions within the manufacturing sector. Awewomom, et al., 2024 stressed the urgent need to avert a global ecological crisis and emphasized the importance of implementing impactful environmental policies. Additionally, the United Nations Environment Programme (UNEP) report in 2013 acknowledged Ghana's ratification of various UN conventions related to environmental issues, including the United Nations Framework Convention on Climate Change (UNFCCC) (Bour et al., 2019).

In Ghana, according to Oteng-Abayie et al. (2022), decoupling CO2 emissions from economic growth poses a challenge due to the increasing reliance on thermal energy sources with relatively high emission factors. Moreover, the drive towards industrialization heavily depends on fossil fuels and gas, further complicating efforts to reduce emissions.

Regarding sustainable practices and environmental sustainability within the manufacturing sector, researchers such as Masrom et al. (2018) and Sarkis (2017) have emphasized the need to address "brown environmental issues" associated with urban and industrial areas. These issues include pollution, inadequate waste disposal methods, and unsustainable farming practices (Bour et al., 2019). Destek et al, 2024; Kindo et al. (2024) have also raised concerns about environmental degradation resulting from industrial activities and stressed the importance of adopting sustainable practices to mitigate these negative impacts (Bour et al., 2019).

In summary, the literature review delves into the intricate relationship between GHG emissions and economic development, with a specific focus on the manufacturing sector. It highlights the importance of understanding emission drivers, implementing effective regulatory frameworks and policies, and promoting sustainable practices. These efforts aim to strike a balance between economic growth and environmental sustainability. The summary is presented in table 1 below.

Table 1: Literature summary

Researchers	**Topic**	**Methodology**
Yang et al., 2021	A race between economic growth and carbon emissions: What play important roles towards global low-carbon development?	Europe and North America played a significant role in global decoupling, with Asia showing the opposite trend. Technological advancements in energy-saving and production efficiency were crucial drivers. However, challenges arose from per capita gross domestic product growth and population expansion, impacting the global carbon-economy decoupling process
Wang et al., 2019	Decoupling economic growth from carbon emissions growth in the United States: The role of research and development	The analysis of decoupling efforts reveals that energy intensity, R&D intensity, R&D efficiency, and sectoral carbon intensity were contributors to separating economic growth from carbon emissions. In contrast, investment intensity, population size, and sectoral energy structure did not play roles in this decoupling. This suggests various policy implications.
Soytas et al., 2009	Energy consumption, economic growth, and carbon emissions: Challenges faced by an EU candidate member	The interesting findings was that carbon emissions may influence energy consumption, yet the opposite causal link is not observed. The absence of a lasting causal connection between income and emissions suggests Turkey can reduce carbon emissions without sacrificing economic growth
Bai et al., 2021	Comprehensive analysis of carbon emissions, economic growth, and employment from the perspective of industrial restructuring: a case study of China	Between 2010 and 2018, empirical findings from China suggest that minor shifts in critical emission sectors can greatly impact economic growth, potentially causing significant job losses with reduced carbon emissions. Promoting labor-intensive sectors, especially the service industry, benefits economic development, carbon emission reductions, and stable employment.
Zhao, 2017	Decoupling economic growth from carbon dioxide emissions in China: A sectoral factor decomposition analysis	The findings reveal that China achieved weak decoupling of economic growth from CO2 emissions from 1992 to 2012, with all its five major sectors showing similar patterns.
Sharif et al., 2021	The effects of infrastructure development and carbon emissions on economic growth	The findings suggest that improving economic growth via road infrastructure development comes with a cost: a deterioration in environmental quality, marked by increased carbon emissions
Kwakwa, 2023	Sectoral growth and carbon dioxide emission in Africa: can renewable energy mitigate the effect?	The study shows that the growth of the agricultural, industrial, and service sectors leads to increased carbon dioxide emissions in the region, while the adoption of renewable energy reduces emissions.

3. Model, Data and Methodology

3.1 Data sources

Time series data covering the years 1990–2022 were utilized in our study to determine the values of the following variables: Total Greenhouse Gasses, gross domestic product, Manufacturing Value Added, Foreign Direct Investment and Total Population. The data was sourced from the World Development Indicators and Ghana Investment Promotion Center.

3.2 Variables specifications

All variables used in the study is described and summarized in table 2 below.

Table 2. Description of Variables.

Variables	Symbol	Definition
Total Greenhouse Gasses	**lnGHG**	Total greenhouse gas emissions in kt of CO2 equivalent are composed of CO2 totals including other biomass burning (such as forest fires, post-burn decay, peat fires and decay of drained peatlands), all anthropogenic CH4 sources, N2O sources and F-gases (HFCs, PFCs and SF6)
Manufacturing Value Added	**lnManuva**	It represents industrial production and the economic contribution of the manufacturing sector.
Gross Domestic Product	**lnGDP**	The total dollar amount of all completed products and services formed in the boundaries of a Ghana over a certain time frame
Foreign Direct Investment	**lnFDI**	The proportion of FDI that is allocated expressly to the manufacturing industry
Total Population	**lnPOP**	Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship.

3.2 Methodology and Approach

3.2.1 Data normalization

In order to convert the raw data into a common format, the wide variations in numerical relationships among the variables were eliminated and all the variable types and the data are put within a more constrained interval. A unit root test specifically, Augmented Dickey Fuller (ADF) test is run to check the stationarity of all variables. The unit root test is shown in table 3 below.

Table 3: Unit root test Updated

	At level	1^{ST} Difference	2^{nd} Difference
InManuva	0.9410	0.0010	0.0000
lnGDP	0.9305	0.0106	0.0000

lnGHG	0.9930	0.0015	0.0000
lnFDI	0.3261	0.0055	0.0000
lnPOP	0.3395	0.0545	0.0000
Lags	1		

3.3 Descriptive statistics

A descriptive analysis is shown in table 4 below to assess variations in the pattern of the variables. The average mean of greenhouse gas emissions is approximately 9.94. This means that, on average, the logarithm of greenhouse gas emissions is close to 9.94. The standard deviation of approximately 0.41 shows that the logarithm of greenhouse gas emissions is 0.41 units. The minimum and maximum values of approximately 9.35 and 10.72 respectively suggest the range within which the observations of the natural logarithm of greenhouse gas emissions fall.

Table 4: Descriptive statistics

Variables	Obs	Mean	Std. dev.	Min	Max
InGHG	33	9.942015	.4051047	9.351615	10.71597
lnGDP	33	23.62397	1.03574	22.32927	25.09469
lnManuva	33	21.22344	1.075276	19.92319	22.85978
lnFDI	33	20.02568	1.809937	16.51014	22.07906
lnPOP	33	16.94944	.2394897	16.55292	17.32634

On the other hand, the average natural logarithm of gross domestic product is approximately 23.62. This means that, on average, the logarithm of GDP is close to 23.62. It's standard deviation of approximately 1.04 indicates that the logarithm of GDP is .04 units whiles minimum and maximum values of approximately 22.33 and 25.09 respectively suggest the range within which the observations of the natural logarithm of GDP fall.

Moreover, the average natural logarithm of manufacturing value-added is approximately 21.22. Meaning, the logarithm of manufacturing value-added is close to 21.22, standard deviation of approximately 1.08 shows that the logarithm of manufacturing value-added is about 1.08 units and the minimum and maximum values of approximately 19.92 and 22.86 respectively suggest the range within which the observations of the natural logarithm of manufacturing value-added fall. Also, the average natural logarithm of foreign direct investment is approximately 20.03. This means that, on average, the logarithm of FDI across the observations is close to 20.03. The standard deviation of approximately 1.81 indicates that the logarithm of FDI varies around this mean by about 1.81 units. The minimum and maximum values of approximately

16.51 and 22.08 respectively suggest the range within which the observations of the natural logarithm of FDI fall.

Finally, the average natural logarithm of population is approximately 16.95. This means that, on average, the logarithm of population across the observations is close to 16.95. The standard deviation of approximately 0.24 indicates that the logarithm of population varies around this mean by about 0.24 units. Whiles the minimum and maximum values of approximately 16.55 and 17.33 respectively suggest the range within which the observations of the natural logarithm of population fall.

3.4 Correlation analysis

The correlation matrix showed in Table 5, sheds light on the connections between the various research variables. The correlation analysis for this study is displayed in table 4.

Table 5: Correlation analysis

	lnGHG	lnManuva	lnGDP	lnFDI	lnPOP
lnGHG	1.0000				
lnManuva	0.9408	1.0000			
lnGDP	0.9406	0.9883	1.0000	1.0000	
lnFDI	0.8590	0.8753	0.9146	1.0000	
lnPOP	0.9862	0.9380	0.9484	0.8968	1.0000

There is a very strong positive correlation of 0.9408 between lnGHG and lnManuva. This suggests a strong relationship between greenhouse gas emissions and manufacturing value-added. Similarly, there is a very strong positive correlation of 0.9406 between lnGHG and lnGDP. This indicates a strong relationship between greenhouse gas emissions and gross domestic product. There is a strong positive correlation of 0.8590 between lnGHG and lnFDI. This suggests a significant relationship between greenhouse gas emissions and foreign direct investment.

There is a very strong positive correlation of 0.9862 between lnGHG and lnPOP. This indicates a very strong relationship between greenhouse gas emissions and population. There is a very strong positive correlation of 0.9883 between lnManuva and lnGDP. This suggests a very strong relationship between manufacturing value-added and gross domestic product. There is a strong positive correlation of 0.8753 between lnManuva and lnFDI. This suggests a significant relationship between manufacturing value-added and foreign direct investment. There is a strong positive correlation of 0.9380 between lnManuva and lnPOP. This indicates a significant relationship between manufacturing value-added and population.

There is a very strong positive correlation of 0.9146 between lnGDP and lnFDI. This suggests a very strong relationship between gross domestic product and foreign direct investment. There is a strong positive correlation of 0.9484 between lnGDP and lnPOP. This indicates a significant relationship between gross domestic product and population. There is a strong positive correlation of 0.8968 between lnFDI and lnPOP. This suggests a significant relationship between foreign direct investment and population. Overall, these correlations suggest strong relationships between the variables, indicating that changes in one variable are likely to be associated with changes in the others. However, correlation does not imply causation, so further analysis would be needed to determine the exact nature of these relationships.

3.5 Variance Inflation Factor

Variance Inflation Factor is a measure of multicollinearity among predictor variables in analysis. The VIF of the variables is presented in table 6 below.

Table 6: Variance Inflator Factor

Variable	VIF	1/VIF
lnGDP	79.76	0.012537
lnManuva	55.56	0.017998
lnPOP	10.71	0.019007
lnFDI	8.38	0.119398
Mean VIF	**38.60**	

The VIF for lnGDP is 79.76, which means there is a high degree of multicollinearity with other variables. The VIF for lnManuva is 55.56, which also indicates a high degree of multicollinearity.
Also, the VIF for lnPOP is 10.71, which is not so high as the other variables but it is still showing some degree of multicollinearity. The VIF for lnFDI is 8.38, which suggests a degree of multicollinearity once more. The reciprocal of the VIF is displayed in the "1/VIF" column which means higher multicollinearity is indicated by a number in the 1/VIF column that is closer to 0.

3.6 Data Analysis

3.6.1 Model Description

An essential formula was derived for the baseline model that this study will use. The links between several variables and Ghana's total greenhouse gas emissions are captured by these formulae. According to the topic; A relationships has been estimated which is; Assessing the relationship between Greenhouse gasses from manufacturing and economic growth. Below is how the formulae is displayed:

$$\ln GHG = \beta_0 + \beta_1 \ln Manuva + \beta_2 \ln GDP + \beta_3 \ln FDI + \beta_4 \ln POP + \varepsilon$$

4. Results and Discussion

4.1. Model and Results

Ridge regression model came about as a result of multiple correlation of variables. Ridge regression come into play when data used is multicollinear in nature. It's a regularization method focused on a new line that doesn't fit where it uses OLS as the estimator. Multicollinearity is when two or more variables have strong relationships with one another if not dealt with it may result in duplicate models and lower predictability's effectiveness and dependability. Ridge regression can overcome this problem by introducing a shrinkage parameter known as lambda λ which is used when independent variables have high degree of correlation.

The function for ridge regression is

Minimize $(\|y - X\beta\|_2^2 + \lambda\| \beta\|_2^2)$

Where:

Y is the vector of observed values

X is the matrix of the predator variables

β *I*s the vector of the coefficient to be estimated

λ is the regularization parameter

Stata/MP 17.0 was used in this study to run the model and analysis.

4.2 Results and Interpretations

Ridge Regression results

In this analysis of greenhouse gas (GHG) emissions and economic development in the manufacturing sector of Ghana using Ridge regression where results are shown in table 7 and 7A below.

Table 7: Ridge regression results

lnGHG = lnManuva + lnGDP + lnFDI + lnPOP

Ridge k Value	0.27000	Generalized Ridge Regression	
Sample Size	33		
Wald Test	377.0693	P-Value > Chi2(4)	0.0000
F-Test	94.2673	P-Value > F (4, 28)	0.0000
(Buse 1973) R2	0.9403	Raw Moments R2	0.9999
(Buse 1973) R2 Adj	0.9317	Raw Moments R2 Adj	0.9999
Root MSE (Sigma)	0.1058	Log Likelihood Function	29.9993
- R2h = 0.9460 R2h Adj = 0.9383 F-Test = 122.69 P-Value > F (4, 28) 0.0000 - R2v = 0.9256 R2v Adj = 0.9150 F-Test = 28.77 P-Value > F (4, 28) 0.0000			

Table 7A: results part 2

lnGHG	Coefficient	Std. err.	t	p>|t|	[95% conf.	Interval]
lnManuva	.0868039	.1296982	0.67	0.509	-.1788708	.3524787
lnGDP	.078726	.1613273	0.49	0.629	-.251738	.4091899
lnFDI	.0225994	.0299157	0.76	0.456	-.0386801	.0838788
lnPOP	.650837	.255666	2.55	0.017	.127129	1.174545
_cons	-.5.243976	3.324316	-1.58	0.126	-12.05353	1.565576

Discussion

The model's modified R-squared value, which ranges from 0.93 to 0.94, shows a good overall fit. This means that the independent variables (lnManuva, lnGDP, lnFDI, and lnPOP) can account for 93% to 94% of the variability in GHG emissions. With p-values around 0, the Wald test and the F-test both imply that the model coefficients are collectively significant. This suggests that at least one independent variable has a substantial impact on greenhouse gas emissions. The independent factors' individual effects on GHG emissions are revealed by the coefficient estimates for each of the variables.

The population's lnPOP coefficient is statistically significant at the 0.05 level, indicating that the size of the population strongly influences greenhouse gas (GHG) emissions in Ghana's manufacturing sector in a positive way. This is consistent with the hypothesis that more people may stimulate the economy and raise emissions as a result. At standard significance thresholds (e.g., $p < 0.05$), other variables like lnManuva (manufacturing value-added), lnGDP (gross domestic product), and lnFDI (foreign direct investment) do not seem to be statistically significant.

Interpretation

The significant positive correlation between population size and GHG emissions means that as population is increasing it may in way results in the rise in demand for goods and services generated by the manufacturing sector, which would then increase in greenhouse gas emissions.

The non-significant coefficients for lnManuva, lnGDP, and lnFDI may indicate that, in this particular context, GDP, foreign direct investment, and manufacturing value-added may not be significant predictors of GHG emissions in Ghana's manufacturing sector; however, more research may be required to fully comprehend these relationships.

The robust overall fit of the model suggests that a considerable proportion of the variability in GHG emissions can be explained by the combination of variables analyzed, implying that economic considerations are important in determining the patterns of emissions in Ghana's manufacturing sector. All things considered, this analysis offers insightful information about the connection between Ghana's manufacturing sector's economic growth and greenhouse gas emissions, emphasizing the significance of taking population size and possibly other economic factors into account when analyzing and mitigating emissions trends.

5.0 Conclusion

The study looked at the complex link that exists between Ghana's industrial sector's economic development and greenhouse gas (GHG) emissions. The results show a strong positive correlation between population size and GHG emissions, indicating that rising population levels increase demand for products and services from the industrial sector and raise emissions. The coefficients for manufacturing value-added, GDP, and foreign direct investment, however, were found to be non-significant, suggesting that in this specific context, these variables may not be the main predictors of GHG emissions within the sector.
Despite the non-significant coefficients for some economic factors, the model demonstrates a strong fit, suggesting that a significant amount of the variability in GHG emissions may be explained by the factors included. This emphasizes how important economic variables are in determining the patterns of emissions in Ghana's industrial sector.

Additionally, the research provides great information on the complex link between GHG emissions and economic growth in Ghana's manufacturing sector. It emphasizes how important it is to take into account the growth of the population as well as maybe other economic aspects in order to understand and solve emissions problems. To fully understand the details of these linkages and to guide more focused policy measures meant to reduce greenhouse gas emissions while promoting sustainable economic growth in Ghana's manufacturing sector, policy implications are however suggested.

5.1 Policy Implication

Based on the findings presented, several policy implications can be suggested to address the relationship between greenhouse gas emissions and economic development in the manufacturing sector of Ghana:

Population Management Strategies: By controlling population growth, the demand for goods and services from the manufacturing sector can be monitored, potentially reducing greenhouse gas emissions associated with increased production (Wang & Azam, 2024). Policies and programs must be implemented to aim at managing population growth through education, family planning, and healthcare services.

Promotion of Sustainable Manufacturing Practices: Manufacturing companies must be encouraged to adopt sustainable manufacturing practices that will prioritize energy efficiency, waste reduction, and the use of renewable resources (Hegab, 2023). This can be achieved through incentives such as subsidies for green technology adoption, tax breaks, and capacity-building programs for manufacturers.

Investment in Clean Energy Infrastructure: Investment such as renewable energy sources (solar, wind, hydro) and energy-efficient technologies must be made in clean energy infrastructure (Kandpal, 2024). This can help reduce reliance on fossil fuels in the manufacturing sector which will then lead to lower emissions while promoting innovation and job creation in the clean energy sector.

Enhanced Monitoring and Reporting: GHG emissions in the manufacturing sector should be monitored by providing policymakers with accurate data to track emissions trends, identify hotspots, and assess the effectiveness of mitigation efforts.

Integrated Economic and Environmental Policies: Integrated policies that take the aims of environmental sustainability and economic growth into account should be created. The implementation of carbon pricing systems, pollution levies, and emission trading schemes may be necessary to encourage cleaner manufacturing methods and adopt the external costs associated with greenhouse gas emissions.

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