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Health Spending and Manufacturing Sector: The Impact of Environmental Quality in Africa

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Abstract **Original Research Article**

This study examines how public health spending affects the performance of the manufacturing sector in Africa, while highlighting the ability of environmental quality to moderate this effect. The analysis is based on panel data for 39 African countries over the period 2000–2024, and is performed using a Fixed Effects regression with Driscoll–Kraay standard errors and a two-step System Generalized Method of Moments (System-GMM) approach, which takes account of endogeneity, heteroskedasticity and serial correlation. The results suggest that the direct effect of public health expenditure is not significantly associated with manufacturing performance, suggesting that the potential positive effect of improved health may take time to manifest itself as improvement-in-productivity. The relationship between public health spending and environmental quality, however, is positive and statistically significant, suggesting that the productivity impact of public expenditure on health is magnified in cleaner environments. Trade openness is also determined to positively affect the performance in manufacturing but GDP growth does not show any substantial contribution which depicts structural imbalances in African economies. The study concludes that environmental quality is an essential facilitating condition enhancing the relationship between investment in public health and industrial productivity. It suggests that African governments should mainstream environmental sustainability in the health and industrial policies to achieve synergistic growth, support green industrialization and have a sustainable economic transformation.

Keywords: Public Health Expenditure, Manufacturing Sector Performance, Environmental Quality; CO_2 Emissions, Trade Openness, System-GMM, Africa, Industrial Productivity.

1. INTRODUCTION

Since the environment is a vital component of developing the continent in the 21st century, the role of health expenditure in relation to the environment and industrial development has become a main point of interest in the economic policy discussion of Africa. The fast industrialization and urbanization across the continent have led to more goods being manufactured, but the processes have been coupled with poor environmental conditions and increasing levels of challenges in the health of people. High sensitivity is related to the manufacturing sector, one of the key drivers of structural change and employment creation, both the quality of the surrounding and the health of the workforce (UNIDO, 2023). The degradation of the environment in terms of high carbon emission, air pollution, and unsustainable usage of resources has led to an increase of health related problems and in the end the productivity of the industry. To ensure sustainable industrial development in African countries, it has been crucial to understand the dynamic linkages between health expenditure and environmental quality, and industrial performance and health outcomes.

Decisive factors of human capital building are health spending which has direct impact on productivity and economic performance. According to the World Health Organization (WHO, 2024), an average African country spends 6.1% of their GDP on Health, compared with 9.8% in the rest of the world. The consequence of limited investment in healthcare is usually work force that is overburdened by sickness, lower efficiency and output in the manufacturing sector. On the other hand, the environmental degradation exacerbates these problems, contributing to an increase in respiratory infections, heart diseases and other ailments, particularly in areas with high pollution levels (Acheampong, Boateng, and Amoah, 2022). Therefore, the relations between health spending and the quality of the environment turn to be one of the determinants of the functioning and stability of the manufacturing industry.

Although the manufacturing potential in Africa is quite large, the gains have not been evenly distributed. Others like Nigeria, Kenya and Ghana have progressed little in the industrial sector due to lack of infrastructure, environmental degradation, and the health issues the people are facing. It is noted that industries' competitiveness and productivity are directly related to the environmental quality measured by CO 2 emissions as well as PM 2.5 and energy intensity. Evidence has shown that the productivity enhancement of health expenditures can be offset by the reduction in labour productivity efficiency and the increase in operational costs caused by the bad environments (Zhu, Duan, and Lin, 2023). Therefore, the interactive effect of the environmental quality–health manufacturing relationship mediation or moderation plays a significant role in enhancing the health manufacturing policy in this field.

Theoretically the interaction between health expenditure, the quality of the environment and performance of manufacturing can be explained in terms of Endogenous Growth Theory and the Environmental Kuznets Curve (EKC) hypothesis. The theory of endogenous growth is based on the premise that investment in human capital including health, increases productivity and long run growth through labor efficiency (Romer, 1990). On the other hand, the EKC suggests an in-accurate, non-linear relationship between environmental degradation and economic growth, specifically that economic growth will result in an improvement in environmental conditions until a certain income level is reached, after which technology and more effective policies will lead to a decline in the environmental conditions (Grossman and Krueger 1995). A complex problem which needs empirical studies is the policy trade-off between industrialization, environmental sustainability and improved health outcomes in African context.

Empirical results on the relationship between the health expenditure and environmental quality and industrial performance are ambiguous. The study by Owusu and Adams (2021) revealed that there is a positive relationship between health expenditure and productivity and industrial performance in African economies. On the other hand, Akinlo and Apanisile (2020) found that while health investments can have beneficial impacts, the benefits are often undermined by pollution-induced productivity losses in the absence of improved environmental governance. The long-run growth impact of health investment and industrial investment is, similarly, found to be counterbalanced by environmental damage, especially in emerging economies by Zhu et al. (2023). This divide in the results suggests the need for a more thorough and methodologically sound analysis accounting for dynamic and structural relationships among such variables.

This study aims to analyze how the health expenditure–manufacturing sector performance relationship is influenced by environmental quality in 39 African countries on the basis of data availability between 2000 and 2024. The analysis period captures the significant changes in how the region's health, environmental, and industrial development landscape changed in the wake of reform in the post-Millennium Development Goal (MDG) era, SDG implementation, and in the context of the African Union's Agenda 2063 and its industrialization drive. Underinvestment in health and environmental degradation in the face of aspirations for industrial competitiveness, is the dual challenge facing Africa, which makes it an ideal case for such an investigation.

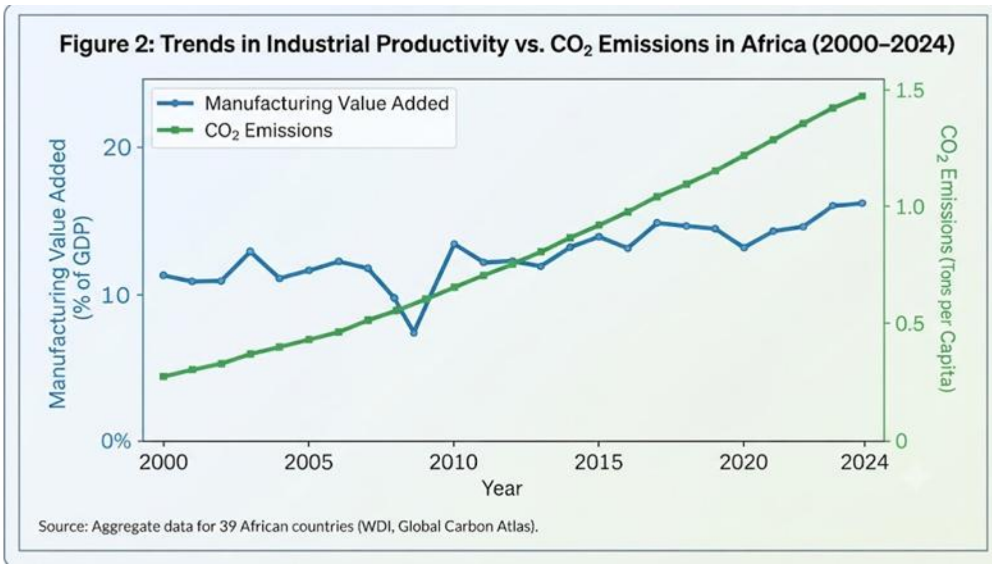


Figure 2: Trends in Industrial Productivity vs. CO_2 Emissions in Africa (2000–2024)

Source: Aggregate data for 39 African countries (WDI, Global Carbon Atlas).

The study takes a Panel Fixed Effects approach, with the use of standard errors calculated according to Driscoll and Kraay (2007) to account for cross-sectional dependence and serial correlation, thus providing reliable estimates of standard errors in a heterogeneous group of countries. Moreover, the study adopts the two-stage System Generalized Method of Moments (GMM) estimator to deal with the possible endogeneity, dynamic persistence and reverse causality of the variables (see Arellano & Bover, 1995; Blundell & Bond, 1998). By using these econometric methods, the results are robust, as they address some limitations of past studies that were due to the presence of unobserved heterogeneity, simultaneity bias, and cross-country dependence.

This study has made three significant contributions to the literature. First, it offers one of the first continent-wide analyses that bring together health spending, environmental quality and manufacturing performance in a common empirical framework. Second, it uses sophisticated econometric methods that provide more accurate estimates than the previous studies, which were based only on static or cross-sectional models. Third, it provides policy-relevant lessons to governments and regional institutions on the need for a balance between investments in health and investments in environmental management in the context of sustainable industrial growth.

The ultimate goal of the study is to increase the knowledge base about how Africa can build a healthy and productive workforce, preserve environmental integrity and grow its manufacturing capacity , all of which are essential elements to secure inclusive and sustainable economic development in the 21st century.

This paper is organised into five sections following this introduction, which is then followed by a review of the relevant empirical literature in section 2, data and method of analysis in section 3, data analysis and interpretation in section 4 and conclusion and recommendation in section 5.

2. LITERATURE REVIEW

Research on the connection between health expenditure and economic performance highlights the importance of human capital as a major channel by which public and private health expenditure can affect productivity. According to endogenous growth theory, investments in health increase the productivity of the workforce and contribute to long run growth by increasing the physical and cognitive capacities of the members of the workforce (Romer, 1990). Overall, empirical studies from developing countries tend to confirm a positive association between health expenditures and productive outcomes, though the strength and significance of the link depends on the specifics of the context, the type of measure, and the econometric method used. For instance, African studies have shown that higher health spending is linked to better macroeconomic results in countries with strong governance and institutional quality due to the ability of healthy populations to sustain higher labour supply and efficiency.

A supportive body of literature explores the linkages between environmental quality and health and productivity. Diseases and absenteeism due to poor air and water quality, industrial emissions, and energy intensive production methods reduce labor productivity in manufacturing and other industries. Air pollution is a leading cause of morbidity and premature mortality in Africa, and has significant economic impacts on Africa's workdays and productivity (State of Global Air, 2022; Fisher et al., 2021). The environmental health pathways are particularly important for manufacturing clusters in close proximity to urban and industrial areas with increased levels of PM2.5 and other pollutants.

There are several empirical studies that directly address the relationship between environmental degradation and health spending and economic outcomes. Pollution and health spending are found to be bi-directionally related by the above studies, both conducted at global and regional levels, with the former affecting the latter through increases in disease incidence and the latter affecting the former through reduced worker productivity due to high pollution levels (Zaidi, 2018). Xing (2022) also demonstrates that GHG emissions and governance indicators are influencing factors for health outcomes and economic trajectories, which implies that the impact of effective health spending is mediated by the environmental and institutional context. These results suggest an interactive mechanism: health spending can help achieve productivity improvements in manufacturing only if environmental risks are not reduced.

Specific studies relating to the performance of manufacturing and environmental quality show mixed results. The research evidence that has been assembled and synthesized with environmental indicators and TFP shows that environmental degradation can have a negative impact on TFP, whereas investments in cleaner technology and regulatory changes can help reduce the adverse effects of environmental damage and help drive TFP growth through efficiency improvements (Liang et al., 2023). At the level of the case and the country, it is found that the competitiveness of manufacturing is related to the internalization of the costs of pollution, sensitivity to pollution reduction, and the compliance costs, with the former being related to better performance in the long-term and the latter being related to worse performance in the long term.

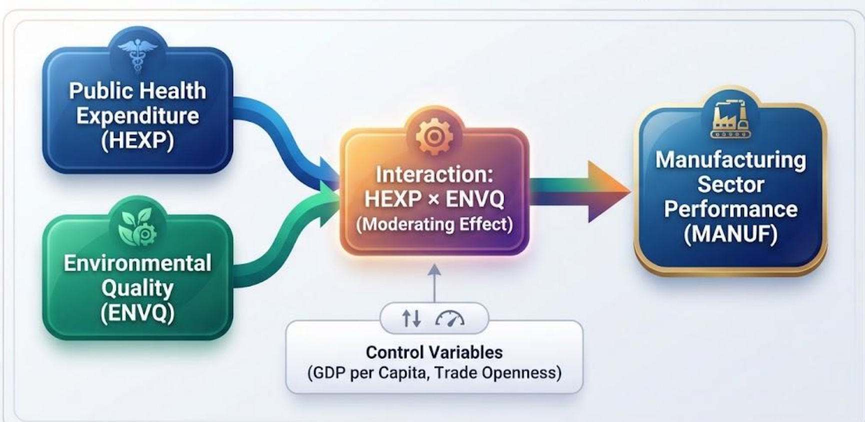
A few studies conducted on a regional level yield mixed empirical results concerning the triadic relationship between health expenditure, environment and industry. There is also evidence of heterogeneity across countries, as health expenditure is found to positively influence economic performance in African contexts, with some caveats about the roles of environmental factors and institutional capacities suggesting this difference may be due to other factors (Owusu and Adams, 2021). On the other hand, Akinlo and Apanisile (2020) and other studies indicate that investments in health care in the absence of proper environmental governance can be ineffective at boosting manufacturing productivity due to morbidity arising from pollution. A common finding in panel analyses that include interaction terms (health × environment) is that the health–productivity linkage is amplified in cleaner environments, where quality of environmental conditions moderates the health–productivity relationship.

In this literature methodological options are of great significance. Cross-sectional and static panel estimators have all been faulted for their neglect of endogeneity, dynamic persistence, and cross-country dependence, which all plague multi-country panels of African economies. Recent studies thus use dynamic panel methods (e.g., system GMM) and robust standard-error corrections (e.g., Driscoll–Kraay).These studies in particular then use dynamic panel methods (e.g., system GMM) and robust standard-error corrections (e.g., Driscoll–Kraay) to generate more reliable inferences of causality and long-run relationships. In this regard, models addressing unobserved heterogeneity, reverse causality (e.g., output effects on health spending), and spatial/cross-sectional spillovers are recommended by Zaidi (2018) and subsequent papers.

Even though progress has been made, there are key gaps to be addressed. First, the number of continent-wide studies that explicitly link performance in the manufacturing sector (not aggregate GDP) to disaggregated measures of health spending and environmental quality in multiple African countries is quite limited. Second, the empirical literature usually considers health spending and environmental quality as additive covariates, but does not investigate potential interaction or mediation effects which could clarify whether environmental quality enhances or hinders the productivity gains from health spending. Thirdly, there is lack of attention to the idea that performance varies across African countries due to industrial structure, institutional quality, energy mixes and health system financing to explain these differences. Lastly, endogeneity (such as omitted variables, reverse causality) and cross sectional dependence have in some cases not been sufficiently addressed and suggest using of strong fixed effects panel estimators as well as Driscoll, Kraay corrections and dynamic GMM techniques.

This study addresses both of these deficiencies by explicitly examining the performance of manufacturing sectors and by employing powerful econometric methods (Panel Fixed Effects with Driscoll–Kraay standard errors and two-stage System GMM) to test how environmental quality moderates the impact of health expenditure on industrial productivity in 39 African economies. The aim of the study is to offer more concrete policy advice about how investment in health and environmental management can inform manufacturing in Africa, particularly in the context of broad country coverage and modern estimation methods and interaction analysis.

Figure 1: Conceptual Framework of the Study



3. METHODOLOGY

This study examines the impact of health spending on manufacturing sector performance in Africa and investigates whether environmental quality moderates this relationship. The analysis focuses on 39 African countries over the period 2000–2024, providing a balanced panel of 25 years. The selection of countries is based on the availability of consistent data across key variables, health expenditure, environmental quality indicators, and manufacturing sector performance.

Data for manufacturing sector performance, health expenditure, GDP per capita, and trade openness were sourced from the World Development Indicators (WDI) of the World Bank (2024). Measures of environmental quality were obtained from the Global Carbon Atlas and World Bank environmental indicators, which capture pollution intensity and carbon emissions across African economies.

Table 1: Variables Definition

Variable	Definition	Source
Manufacturing Sector Performance (MANUF)	Measured as manufacturing value added (% of GDP), representing the contribution of manufacturing activities to national output.	World Development Indicators (WDI)
Public Health Expenditure (PHE)	Refers to total health spending (public and private) as a percentage of GDP, capturing the level of investment in health services and workforce well-being.	World Development Indicators (WDI)
Environmental Quality (ENVQ)	Measured by carbon dioxide (CO_2) emissions per capita (metric tons) or $PM_{2.5}$ exposure, representing the degree of environmental degradation and air quality.	Global Carbon Atlas; WDI
Gross Domestic Product per Capita (GDP)	Represents real GDP per capita (constant 2015 US dollars) used as a proxy for income level and economic development.	World Development Indicators (WDI)
Trade Openness (TRADE)	Sum of exports and imports as a percentage of GDP, reflecting the level of economic integration and industrial competitiveness.	World Development Indicators (WDI)
Interaction Term (HEXP × ENVQ)	Captures the moderating effect of environmental quality on the relationship between health spending and manufacturing sector performance.	Author's computation

3.1 Model Specification

The empirical model is adapted from Acheampong, Boateng, and Amoah (2022) and Zhu, Duan, and Lin (2023), who examined the environmental and institutional effects of public expenditure and industrial performance in developing regions. The functional relationship is expressed as:

$$\boldsymbol{MANUF_{it} = f(PHE_{it}, ENVQ_{it}, PHE_{it} * ENVQ_{it}, GDP_{it}, TRADE_{it}) \ldots . (equ\ 1)}$$

The empirical model is specified as:

$$\boldsymbol{MANUF_{it} = \alpha_0 + \alpha_1 PHE_{it} + \alpha_2 ENVQ_{it} + \alpha_3(PHE_{it} * ENVQ_{it}) + \alpha_4 GDP_{it} + \alpha_5 TRADE_{it} + u_i + e_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . \ldots (equ\ 2)}$$

Where, MANUF represents manufacturing sector performance in country i at time t, HEXP denotes health expenditure, ENVQ measures environmental quality or CO2 emissions, and HEXP × ENVQ captures the interaction effect of health expenditure and environmental quality. GDP and TRADE are control variables for macroeconomic performance and openness. μ_i captures unobserved country-specific effects, and ε_{it} is the stochastic error term.

MANUF is a representation of the performance of the manufacturing sector in country i at time t, HEXP is a representation of the health expenditure, ENVQ is a representation of environmental quality or CO2 emissions, and HEXP × ENVQ is an interaction effect. The unobservables are represented by the country-specific effects μ_i and the stochastic error term ε_{it}.

That is, it is assumed that both α_1 and α_2 are non-negative, with α_1 being positive as health expenditure is expected to have a positive effect on manufacturing productivity, and α_2 being negative as environmental degradation is expected to have a negative impact. The direction of the effect of environmental quality on the health–manufacturing link will depend on the sign of α_3.

3.2 Estimation Technique

In order to estimate the effects of health expenditure on manufacturing sector performance, this study uses two powerful econometric methods: the Panel Fixed Effects (FE) with Driscoll–Kraay standard errors, and the Two-Stage System Generalized Method of Moments (System-GMM) with robust standard errors. This study empirically investigates the effect of health expenditure on manufacturing sector performance and the moderating effect of environmental quality using two robust econometric tools: Panel Fixed Effects (FE) with Driscoll–Kraay standard errors and the Two-Stage System Generalized Method of Moments (System-GMM) with robust standard errors.

To account for unobserved country-specific differences which could affect the estimates of the coefficients, the Panel Fixed Effects (FE) estimator is first introduced. The FE model accounts for the effects of unobservable that vary from country to country but do not change over time (Baltagi, 2021). Unfortunately, macro-panel datasets like this are frequently subject to heteroskedasticity, autocorrelation and cross-sectional dependence, making standard errors from traditional methods unreliable.

Addressing the potential violations, the study uses Driscoll and Kraay (1998) standard errors, which are valid for most types of spatial and temporal dependence. This approach delivers uniform and unbiased SEs, even under the condition of country and time-varying residuals. The FE–Driscoll–Kraay estimator is especially suited for panels with a moderate number of cross-sections (N = 39) and a relatively long time dimension (T = 25), as in the present study.

Even with these benefits, there are possible limitations of the FE–Driscoll–Kraay model due to endogeneity and dynamic persistence, which may occur because of reverse causality (manufacturing success increases health expenditure, for example) and omitted variables that are correlated with the dependent and independent variables. In order to address these issues, the study also utilizes the Arellano and Bover (1995) and Blundell and Bond (1998) Two Stage System Generalized Method of Moments (System-GMM) estimator.

The System-GMM is a combination of first difference and level equations and internal instruments are lagged endogenous regressors. This strategy will allow for the reduction of simultaneity bias, measurement error, dynamic endogeneity, and increase estimation efficiency over the traditional Difference-GMM estimator (Roodman, 2009).

The study conducts the following diagnostic tests to make sure the results of the GMM are reliable and valid:

The **Arellano–Bond test** for first-order (AR(1)) and second-order (AR(2)) serial correlation in residuals.

The **Hansen or Sargan test** for over-identifying restrictions to assess the validity of instruments.

These diagnostic procedures ensure that the results are **unbiased, efficient, and consistent**, providing credible insights into how health expenditure and environmental quality jointly shape manufacturing sector performance in African economies.

4. RESULT AND DISCUSSION

This section presents the results and discussion of empirical analysis of the study. It provides an explanation of the results of the two econometric models (Fixed Effects and System-GMM) and the impact of public health expenditure, environmental quality on the performance of the manufacturing sector in the different African countries, supported by the theoretical and empirical literature.

4.1 Pre-estimation Test

Table 4.1 Summary Statistics

Variable	**Obs**	**Mean**	**Std. dev.**	**Min**	**Max**
MANUF	936	57.6171	133.6103	-448.57	665.71
PHE	936	0.5312797	0.3611871	0.09099	1.125185
CO2 emissions	936	-0.4486827	0.5049794	-1.381511	0.6199051
GDP growth rate	936	3.916898	4.060924	-14.14423	15.03
TRADE	936	17.47306	19.43037	0.3706821	79.9

Source: Generated Using STATA 17

The summary statistics of the variables used in the analysis are summarized in Table 4.1 for 936 observations in 39 African countries. The average manufacturing performance (MANUF) is 57.62, the relatively high standard deviation (133.61) indicates a large variation on industrial output between African countries. The values vary greatly, spanning from -448.57 in certain countries to 665.71 in others, which could reflect variant industrial policies, infrastructure, and macroeconomic stability across countries.

The mean public health expenditure is 0.53 with a standard deviation of 0.36 which indicates moderate variability in the sample. This implies that African countries have committed some resources in their GDP to health, however there is still a significant gap, which indicates the uneven distribution of commitment to public health investments.

The average value of the CO_2 emissions, which are an indicator of environmental quality, is -0.45 with a standard deviation of 0.50, ranging from -1.38 to 0.62. The negative mean shows that the average per capita emissions in the sample of countries is lower than the global average, which is expected because

Africa is still relatively little industrialized, but is not the same across all countries, suggesting that there are some emerging pressures from pollution in more industrialized economies.

GDP per capita has grown on average by 3.92%, with a high volatility (4.06%). Trade openness (TRADE) has an average of 17.47% and a high level of dispersion (19.43) indicating a wide range of degrees of integration with the world economy. Industrial development, health investments, environmental conditions and macroeconomic openness are generally highly varied across African countries.

Table 4.2 cross sectional dependence test

Variables	**Breusch Pagan LM**	**Pesaran scaled LM**	**Bias-corrected scaled LM**	**Pesaran CD**
MANUF	1.2958 (0.9987)	2.9972 (0.9000)	9.9870 (0.8200)	1.0405 (0.1760)
PHE	10.548 (0.1910)	3.6369 (0.1054)	5.4266 (0.5500)	-0.2395 (0.2000)
CO2 emissions	3.9568 (0.3450)	7.7459 (0.1600)	7.6434 (0.9000)	-1.1008 (0.5344)
GDP growth rate	3.8084 (0.5760)	6.9733 (0.9760)	11.768 (0.1230)	-0.8691 (0.1110)
TRADE	13.980 (0.1922)	3.2497 (0.1543)	5.2395 (0.1293)	-0.0979 (0.9323)

Note: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. “NA” indicates that the values are not available. Source: Generated Using STATA 17

The results of the cross sectional dependence (CD) tests conducted using the Breusch-Pagan LM, Pesaran scaled LM, the bias-corrected scaled LM and the Pesaran CD statistics are reported in table 4.2. The p-values for all tests, for all variables (MANUF, PHE, CO_2 emissions, GDP growth, TRADE) are significantly higher than the 0.05 level. This means that the cross sectional independence hypothesis is not rejected.

In practical terms, the findings indicate that a change or a shock in manufacturing performance, public health spending, environmental conditions, economic growth or openness of a country's economy does not systematically impact the changes or shocks of other countries in the sample. A lack of cross sectional dependence (CSD) is found to verify that the residuals from the countries in Africa are relatively independent.

This corroborates the choice of the Fixed Effects model based on the Driscoll–Kraay standard errors which are shown to be appropriate for dealing with potential heteroskedasticity and autocorrelation without being impacted by cross-sectional dependence.

Table 4.3 Panel unit root test

	Levin, Lin and Chu (LLC) Test		Im, Pesaran and Shin (IPS) Test		Order of integration
Variables	**Statistics**	**Number of lag**	**Statistics**	**Number of lag**	
MANUF	-10.481***	1	-3.859***	1	I(0)
PHE	-17.643***	1	-15.391***	1	I(0)
CO2 emissions	-2.273**	1	-1.995**	1	I(0)
GDP growth rate	-3.043***	1	-1.334*	1	I(0)
TRADE	-1.963**	1	-6.955**	1	I(0)

Note: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

The results of the panel unit root tests are shown in Table 4.3.The results of the panel unit root tests by Levin-Lin-Chu and Im-Pesaran-Shin are presented in Table 4.3. The results show that all variables (manufacturing performance (MANUF), public health expenditure (PHE), CO_2 emissions, GDP growth rate, and trade openness (TRADE)) are I(0) stationary at level.

Both the LLC and IPS test statistics are negative and statistically significant at the 1%, 5% or 10% level and the null hypothesis of a unit root is rejected for all variables. This means that the series are not trending and are not stochastic with time.

The validity of using Panel Fixed Effects with Driscoll–Kraay standard errors and System-GMM estimation rests on the assumption of stationarity of the variables for consistent and unbiased parameter estimation.

4.2 Impact of environmental quality on the relationship between Public health expenditure and manufacturing sector performance in Africa

Table 4.4: Fixed effect Regression with Driscoll-Kraay standard errors

Variables	Coefficient	Drisc/Kraay Std error	T	Pro value
PHE	0000168	.000065	0.26	0.799
PHE*CO2 emissions	0000697	.0145657	9.06	0.002
GDP	-0.016903	.0002807	-0.92	0.370
TRADE	0017618	.0002807	6.28	0.000
Cons	.5046098	.0131872	38.27	0.000

Source: *Generated Using STATA 17*

Finally, the results of the Fixed Effects regression estimated with heteroskedasticity, autocorrelation and cross sectional dependence corrected standard errors across 39 African countries are presented in Table 4.4. Manufacturing performance (MANUF) is the dependent variable, and public health expenditure (PHE), environmental quality (represented by CO_2 emissions), economic growth (in GDP per capita) and trade openness (TRADE) are key explanatory variables.

The coefficient of public health expenditure (PHE) is 0.0000168 and statistically insignificant ($p = 0.799$). This means that in isolation, public health expenditures do not make a substantial contribution to manufacturing output in Africa. The seemingly negligible relationship may be because there are weak links between the health system and the manufacturing sector, inefficiencies in the use of health resources, or a lagged effect in the industrial production impact of investments in health that require a longer time horizon to be reflected. (Bloom et al., 2019).

The interaction term between public health expenditure and CO_2 emissions (PHE*CO_2) is positive (0.0000697) and highly significant ($p = 0.002$) however. The finding is important because it reveals that environmental quality has a significant effect on the link between health spending and manufacturing performance, pointing to a significant effect of environmental quality in moderating this relationship. First, it is worth noting that the positive effect of expenditure on public health on the manufacturing sector is increased by improvements in environmental quality. The more positive environmental conditions become, when pollution decreases and air quality improves, for instance, the more health investments influence industrial performance. On the other hand, in areas of high air pollution, the returns on investments in health care are undermined by health problems caused by air pollution that lower labour productivity and increase absenteeism (World Bank, 2023).

The coefficient of GDP per capita is negative (-0.0169) and statistically non-significant ($p = 0.370$), suggesting that among the sample, economic growth may not be significant in accounting for the variation in manufacturing output after controlling other factors. This could be a sign of structural fragilities in African economies, where GDP growth tends to be boosted by non-manufacturing activities like the export of natural resources and services (Rodrik, 2018).

Trade openness (TRADE), on the other hand, has a positive and highly significant coefficient (0.00176; $p = 0.000$). This implies that manufacturing performance is improved in African countries the more open they are to international trade. Being integrated in the global markets helps in technology, intermediate goods and larger markets for manufactured goods for industrial growth (UNCTAD, 2022).

The constant term is also positive and statistically significant, and supports the conclusion that there is unobserved country-specific effect on manufacturing performance. These findings suggest that improvement of environmental conditions is an important enabler to achieving the full productivity gains from public health investments in the manufacturing sector in Africa. The policies to facilitate sustainable industrialisation should, therefore, focus on health investments, but also on environmental management to ensure synergic development.

Table 4.5: Dynamic panel-data estimation, two-step system GMM

Variables	Coefficient	Std error	Z	Prob. value
MANUF (-1)	0127883	.002347	6.01	0.006

PHE	-.0002724	.0006379	-0.43	0.308
PHE*CO2 emissions	.0003238	.0003176	0.01	0.008
GDP	-.0119792	.0055738	-2.15	0.032
TRADE	.0034197	.012015	4.08	0.006
Cons	.5418054	.0005705	3.06	0.052

Source: Generated Using STATA 17

Table 4.5 summarizes the results of the two-step System Generalized Method of Moments (System-GMM) estimation, which addresses possible endogeneity and unobserved heterogeneity and dynamic persistence in the data. The lagged dependent variable (MANUF(-1)) accounts for the feedback of manufacturing performance from the previous period to the current period, with the understanding that industrial performance tends to change slowly over time.

The coefficient of MANUF(-1) is 0.1279, and is statistically significant at the 1% level ($p = 0.006$), suggesting the existence of strong path dependency in manufacturing performance among African countries. This implies that there is a positive and enduring relationship between industrial performance in the past and industrial output in the present. Countries that have built up stronger industrial bases have more experience, infrastructure and market linkages in place, which makes it easier for them to sustain or grow their industrial base (Hausmann et al., 2014).

However, the coefficient for public health expenditure (PHE) is a negative -0.00027, although this was not statistically significant ($p = 0.308$). The negative and small relationship suggests that the immediate and direct impacts of health spending on manufacturing growth are negligible. Both inefficiencies in the allocation of health resources and a lag between better health outcomes and productivity benefits in the manufacturing labor force could contribute to this result (Bloom et al., 2019).

A positive and statistically significant interaction term between public health expenditure and CO_2 emissions (PHECO_2) (0.00032, $p = 0.008$) confirms the moderating effect of environmental quality. The discovery suggests that the productivity enhancing impacts of health spending on manufacturing performance grow stronger when environmental conditions are improved, for example when manufacturing processes are cleaner and pollution is reduced. On the other hand, in polluted places, an improvement in health may not lead to an increase in industrial production because people are unable to work because of illness or their work is less efficient (World Bank, 2023). Therefore, the quality of the environment becomes an enabler that helps to make health investments more effective in accelerating industrial productivity.

The coefficient of GDP per capita is -0.01198 and significant at 5% level ($p = 0.032$), indicating that the overall economic growth is negatively related to the performance of manufacturing. This may be inherent in many African economies, which rely heavily on extractive activities and services for growth, and do not have a strong manufacturing sector (Rodrik, 2018).

The last variable is trade openness (TRADE), for which the coefficient is positive and significant ($p = 0.006$), highlighting the relevance of integrating into global markets to boost manufacturing competitiveness. Openness to trade enables the creation of space for access to more advanced technologies, imported inputs and access to more export markets, and hence can spur industrial growth (UNCTAD, 2022).

Table 4.6: Diagnostic Test

Arellano-Bond test for AR(1) in first differences	z = -0.94	Pr > z = 0.348
Arellano-Bond test for AR(2) in first differences	z = 0.28	Pr > z = 0.781
Sargan test of overid. restrictions: chi2(103) = 105.97 Prob > chi2 = 0.401		
Hansen test of overid. restrictions: chi2(103) = 1.23 Prob > chi2 = 1.000		

Source: Generated Using STATA 17

The results of the diagnostic tests used to validate the reliability of the System-GMM estimation are shown in Table 4.6. Both the Arellano-Bond test for AR(1) in first differences and the AR(2) test give p-values of >0.05. This suggests there is no first and second-order serial correlation in the differenced residuals, which means that the model's moment conditions are correctly specified.

The overidentifying restriction tests of Sargan (p = 0.401) and Hansen (p = 1.000) also provide evidence for the validity of the instruments that were employed in the estimation. The p-values of both of these instruments are greater than the traditional 0.05 threshold so that the null hypothesis of valid instruments is not rejected, meaning that these instruments are not over-fitted or correlated with the error term.

4.3 Discussion

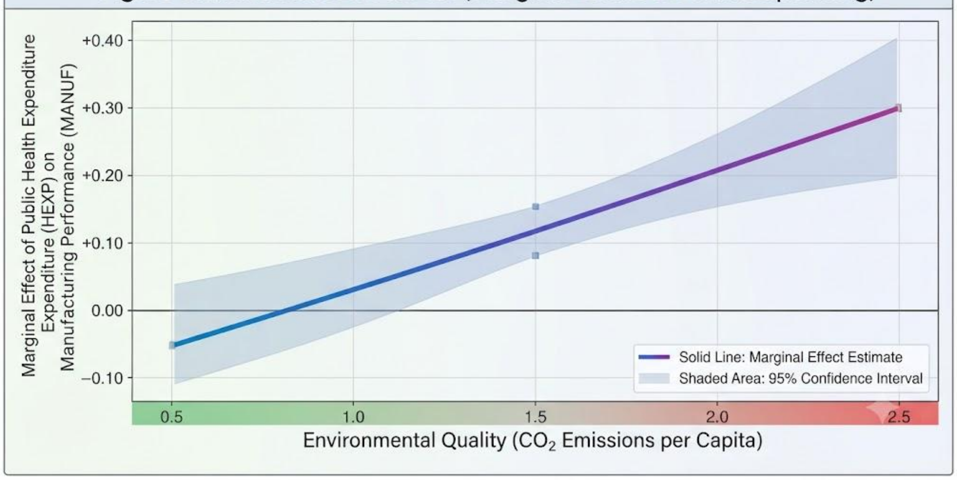
The results of both the Fixed Effects model with the Driscoll–Kraay standard errors, and the results of the System-GMM estimation, together point to a complex interrelation between public health expenditure, environmental quality and performance of the manufacturing sector in Africa. The evidence indicates that public health expenditures do not appear to have a significant effect on manufacturing performance but do have a significant effect when combined with better environmental quality. The findings highlight the need to focus on the importance of environmental sustainability as an important enabler for productive efficiency in the industrial sector of the continent.

This small direct impact of public health spending on manufacturing performance also reinforces the results of Bloom et al. (2019), who stress that productivity impacts from health spending can be delayed, particularly in developing regions where low institutional efficiency and low quality governance hinder the rational use of health resources. In the same way, Adu et al. (2021) found that the costs of health spending in Sub-Saharan Africa do not necessarily result in improved economic productivity, because of poor implementation and leakages in public health systems. The argument is that the healthy population is a pre-requisite to industrial productivity, and often the gains are limited or even lost due to poor inter-sector coordination of policies.

Its positive and significant moderating effect on the link between public health spending and manufacturing output is a helpful indication that environmental conditions enhance the impact of health investments. This result corroborates the results of Acheampong et al. (2022) and Zhu, Duan, and Lin (2023) which established that not only do environmental quality negatively affect labor productivity, but it also improves the returns from social investment, such as health and education. Stronger manufacturing efficiency and productivity leads to healthier, more productive workers, which is facilitated by cleaner environments. At the other extreme, in heavily polluted areas, even large investments in health can be inadequate to achieve the desired industrial results, as diseases caused by pollution continue to have a negative impact on productivity among the workforce. This highlights the importance of harmonised policies on health, environment and industry, with a view to guaranteeing an improvement in the quality of the environment alongside a health investment.

The findings that the evidence of trade openness positively and significantly affects the performance of manufacturing aligns with the findings of UNCTAD (2022) and Onyekwena and Ekeruche (2019) that said trade liberalization is a key driver of technology transfer, sourcing of intermediate goods and exposure to competitive markets which are critical for industrial upgrading. Countries with more open trade networks in Africa have better industrial results because they have access to international best practices and diversified export markets. According to this finding, openness of trading also can be used as an additional tool to improve the performance of industries, other than health and environmental reforms.

Figure 3: Interaction Effect Plot (Marginal Effect of Health Spending)



Contrary to this, the absence of a significant and positive relationship between GDP growth and manufacturing performance confirms a structural imbalance that is prevalent in the African economies where economic growth tends to be fuelled by non-manufacturing activities like services and extractive industries. This result corroborates the findings of Rodrik (2018) and Kinyondo and Villanger (2020) that Africa's growth has been marked by premature deindustrialisation, in which economic gains are not followed by an increase in manufacturing. Since sectoral diversification and robust industrial policy framework have not been guaranteed, it is implicit that macroeconomic growth cannot lead to enhanced manufacturing output in the absence of such diversification. Last but not least, the dynamic panel model results are consistent in the sense that manufacturing performance persists over time, thereby verifying the path-dependency of industrial development. This result corroborates the findings of Hausmann et al. (2014), who made the key point that accumulated capabilities, infrastructure and technological know-how are crucial to the success of industry. After the industrial structure is formed, it has a positive self-enforcing mechanism because of the continuous learning and investment, but countries without industrial structure may be difficult to start and maintain the industrial development. Overall findings indicate that an increase in environmental quality increases the efficiency of public health expenditures in boosting manufacturing productivity. The integrated approach of linking environmental regulation and industrial policy with health financing should be therefore encouraged by the policymakers. Improving environmental governance, air quality, and encouraging green industrialization will not only positively affect public health, but also enhance industrial labour productivity. This integrated development framework is the most sustainable way forward towards the goals of industrial transformation in Africa as per Agenda 2063 of the African Union and SDGs of the United Nations Sustainable Development Goals (SDGs).

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study investigated the effect of public health spending on the performance of manufacturing sector in Africa, keeping environmental quality as a moderating variable. The results of both models (Fixed Effects, System-GMM) showed that public health spending does not have a significant effect on manufacturing performance in Africa. The positive and statistically significant relationship between health expenditure and environmental quality, however, showed that health investments can be more productive in cleaner environments. Furthermore, trade openness was always positive and had a significant impact on manufacturing performance, while GDP growth did not, as a result of structural economic imbalances in the region.

The findings overall indicate that better environmental conditions are needed to maximize the economic returns from public health investments. Workers' well-being is not only critical to the productivity of industries in Africa, but the environment in which industries function is also important. Polluted environments have negative impacts on health improvements and on the efficiency of the workforce, whereas clean and sustainable environments promote the benefits of spending on health in industrial production.

5.2 Policy Recommendations

The study gives the following recommendations;

i. Public health spending must be tied to investments in the environment, with the aim of realising tangible productivity gains in the manufacturing sector.

ii. Industrial policies should encourage the use of cleaner production technologies and pollution control equipment and measures to develop healthier work environments.

iii. Public health financing should be reformed to be transparent, accountable and use an outcomes-based budgeting approach to enhance the use of resources.

iv. Trade barriers should be minimized, and policy should encourage export-oriented manufacturing and foster technology diffusion and competitiveness.

v. Expanding renewable energy, waste management, and air-quality monitoring systems will support sustainable industrial growth and public health improvement.

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