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Nexus of Trade and Industrial Sector on Human Capital Development in Selected ECOWAS Countries

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Abstract: This study investigates the nexus of trade openness and industrial sector on human capital development in Nigeria, Côte d'Ivoire, and Togo over the period 1994 to 2023. This study examines the relationship between trade openness, industrial sector, and human capital development in the selected West African countries using a quantitative panel data method. Variables of the study include Human Capital Index (HCI) as the dependent variable while Trade Openness (% of GDP), Industrial share (% of GDP) and Interaction term between Trade Openness and Industrial Value Added as independent variables. The study utilized data from the World Bank's World Development Indicators and relevant country statistical agencies. The findings shows that trade openness (β = 0.0042), and industrial sector (β = 0.0060 individually contribute positively to human capital development. However, the significant negative interaction result between trade openness and industrial share (-.00009) indicates that the benefits of trade openness on human capital diminish as the industrial sector grows larger. Based on the findings, this study recommends that policymakers should design trade and industrial policies that complement rather than substitute each other. Furthermore, to mitigate the negative interaction effect, targeted investments in skill development aligned with industrial diversification can enhance the absorptive capacity of the workforce and ensure more inclusive human capital benefits from trade.

Keywords: *Trade, Industrial Sector, Investment, Human Capital Development.*

JEL Classification: *F15.*

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I. INTRODUCTION

Human capital development has been considered a critical factor for sustainable economic growth and social development in emerging economies (Barro, 2001; Becker, 1993). There are various ways in which a country can enhance human capital development among which are trade and industrial growth which have been identified as key drivers that potentially influence human capital development. Theoretically, increased trade and industrial growth are expected to enhance human capital through higher income, better job opportunities, improved access to goods and services, and increased public revenues for social investment (Barro, 1999; Romer, 1990).

However, in the ECOWAS sub region countries such as Nigeria, Côte d'Ivoire, and Togo face considerable challenges in improving human capital, despite reforms and investments in education and health sectors (World Bank, 2022). While policies promoting trade liberalization and industrial development have been implemented, the extent to which these factors, individually and jointly, influence human capital development is not well understood and need to be investigated in the ECOWAS sub region.

Additionally, empirical evidence in the ECOWAS sub region reveals a more complex and, at times, contradictory relationship. For example, while Nigeria has experienced significant trade expansion and industrial output growth since the mid-1990s, these gains have not consistently translated into improved educational or health outcomes (Adewale and Taiwo, 2021; Olayemi, 2020). Similarly, although Côte d'Ivoire has made strides in industrialization, particularly in agro-processing and manufacturing, the benefits have often been unevenly distributed and constrained by weak institutions and infrastructural deficits (AfDB, 2023). In the case of Togo, limited industrial capacity, a narrow export base, and low public investment in education and health have

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slowed progress in human capital development despite gradual trade openness (World Bank, 2022).

Studies have also shown that Human Development Index (HDI) levels are generally lower in ECOWAS than the global average and the countries have struggled with industrial development due to a lack of diversification, poor infrastructure, and inadequate investment in human capital (Torres and Seters; 2016). For instance, the overall HDI performance in the region is among the lowest, with an HDI of 0.48 (ECOWAS, 2021) compared to the sub-Saharan Africa average of 0.55 and the average of other emerging countries, like South Africa, at 0.64.

Thus, the nexus between trade and the industrial sector in human capital development cannot be overemphasized. This is occasioned by the fact that trade openness enables the flow of goods, services, and ideas among countries, which may increase the demand for skilled labor and incentivize investment in education (Grossman & Helpman, 1991) while industrialization contributes to structural transformation, generating employment opportunities and fostering technological progress that support human capital accumulation (Kuznets, 1966).

Previous empirical studies often treat trade openness and industrialization as independent factors, neglecting their joint effects (Felipe & Hasan, 2006; Adeoti, 2014). This gap limits policymakers' ability to design integrated strategies that harness the synergies between trade and industrial growth for human capital enhancement. Similarly, limited longitudinal data for these countries restricts comprehensive analysis of trends over time. This study thus, empirically investigate trade openness-industrial sector nexus on human capital development in Nigeria, Côte d'Ivoire, and Togo over the period 1994 to 2023.

II. LITERATURE REVIEW

The nexus of trade openness, industrial sector, and human capital accumulation is grounded in several economic growth and development theories. Nevertheless, this study adopts human capital theory (Schultz ;1961 and Becker; 1963), endogenous growth models (Romer, 1990), and structural transformation theory (Kuznets, 1966) to analyze how trade openness and industrial sector, individually and interactively, shape human capital development in selected ECOWAS countries.

Chabi and Saygılı (2024) investigates the role of trade openness to the structural change process in ECOWAS countries. The findings of the study show that the production structural change process is significantly and positively influenced by the extent of trade openness. Higher openness levels are associated with more production reshuffling between sectors. The study further found that in considering labor structural change, more openness tends to trigger the reshuffle of labor toward less productive sectors. These findings emphasize the importance of external effects in the structural change process in ECOWAS countries.

Balogun, Tella, Adelowokan, Ogede, and Adegboyega (2024) adopts panel autoregressive distributed lag (ARDL) using both the Pool Mean Group (PMG) estimator and Cross-Sectional Autoregressive Distributed Lag (CS-ARDL) methods to investigate the relationship among trade openness, poverty, and human capital development to attain sustainable development across a panel of ten ECOWAS economies over a 34-year period (1987–2020). The results show that poverty has a consistent negative long-run impact on sustainable development, while human capital is positively related with sustainability over the long term. Trade openness does not have a significant relationship with sustainability in both the short and long run. Furthermore, inflation is insignificantly related to sustainability while exchange rates demonstrate mixed effects. The findings suggest the need for integrated policy mixes prioritizing multidimensional poverty reduction and human capability enhancement to promote sustainability objectives across both short- and long-term horizons in ECOWAS countries.

Olanrele and Oshota (2025) employs Autoregressive Distributed Lag (ARDL) in their study for the main analysis and the Dynamic Ordinary Least Square (DOLS), Fully Modified Ordinary Least Squares (FMOLS) and Canonical Cointegration Regression (CCR) for robustness checks to examine the effect of trade per capita on human development outcomes in Nigeria over the period 1990–2022. The results show that trade per capita significantly increases human development, particularly by improving gross national income per capita and life expectancy, while its effects on education outcomes are less consistent. Furthermore, GDP per capita growth is found to negatively affect life expectancy in some cases, suggesting that economic growth alone does not guarantee human development except accompanied by equitable resource distribution. Public health expenditure positively stimulates both life expectancy and education, emphasizing the importance of targeted investments. The findings highlight the need for policies that enhance trade openness while simultaneously addressing infrastructural gaps and investing in health and education sectors to ensure sustainable and inclusive development.

Oloke, Olabisi, Johnson, Awofala, and Aderemi (2025) utilize the FMOLS method to investigate the nexus between foreign capital inflows and human capital development in Nigeria spanning from 1990 to 2020. Findings show that trade openness has a negative and significant relationship with human capital development. Similarly, FDI and portfolio investment have a significant inverse relationship with human capital development in Nigeria. However, official development assistance has a direct relationship with human capital development with a significant relationship at 10 percent level of significance. Similarly, exchange rate has a positive and significant relationship with human capital development. Both external debt and remittances have insignificant positive relationship with human capital development in Nigeria.

Oshota and Wahab (2022) empirically examines the extent to which institutional quality affects bilateral trade flows in ECOWAS using gravity model for the period from

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2000 to 2018. Specifically, the study employs the negative binomial pseudo-maximum likelihood estimator (NBPML). The findings show that institutional variables with both aggregated and disaggregated measures of the quality of institutions significantly and positively impact trade flows in ECOWAS and on its sub-groups, WAEMU and WAMZ. Findings further indicate that for both importing and exporting countries, reduced corruption, effective rule of law, and effective government coincide with more trade among member countries.

Ewane and Ewane (2024) examines the effect of human capital development on industrial sector growth in Sub Saharan African (SSA) countries using mean group (MG), pooled mean group (PMG), and dynamic fixed effect (DFE) heterogeneous dynamic panel modeling. The result indicates that government expenditure on education has a negative and significant effect on industrial sector growth while life expectancy has a positive and significant effect in the short run. Nevertheless, in the long run, tertiary school enrolment and life expectancy have a positive and significant effect while government expenditure on education has a negative but insignificant effect on industrial sector growth. The results further show that there is a long run asymmetry nexus between human capital and industrial sector growth.

Kramo (2022 compares the effect of trade between Côte d'Ivoire and other African countries on productivity and the effect of trade between Côte d'Ivoire and the rest of the world on productivity using the Dynamic Least Squares (DOLS) and Cointegration Canonical Regression (CCR) methods of Park (1992) to analyze the relationship between productivity and trade openness in Côte d'Ivoire over the period 1980-2019. The results show that the effect of trade between Côte d'Ivoire and African countries on productivity contrasts from the effect of trade between Côte d'Ivoire and the rest of the world on productivity. Similarly, exports from Côte d'Ivoire to Africa have a positive and significant effect on productivity. while Côte d'Ivoire's imports from Africa have a negative and significant effect. Côte d'Ivoire's imports from the rest of the world positively and significantly affect productivity. On the other hand, exports from Côte d'Ivoire to the rest of the world (outside Africa) have a negative and significant effect on productivity.

Choramo, Abafita, Gandica, and Rocha (2024) in their study utilize complex network analysis and dynamic panel regression techniques to identify factors driving economic integration in Africa. The results show that economic development, institutional quality, regional trade agreements, human capital, FDI, and infrastructure positively influence a country's position in the African trade network. Conversely, the global financial crisis, trade costs, and regional overlapping memberships negatively affect network-based integration. Findings also show that enhancing a country's connectivity in the African trade network involves identifying key economic and institutional factors of trade partners and strategically focusing on continent-wide agreements rather than regional ones to boost economic growth.

III. METHODOLOGY

This study adopts a quantitative panel data approach to investigate the relationship between trade openness, industrial sector, and human capital development in three selected ECOWAS countries (Nigeria, Côte d'Ivoire, and Togo). The dataset covers a 30-year period from 1994 to 2023 with Human Capital Index (HCI) as the dependent variable while Trade Openness (% of GDP), Industrial share (% of GDP**)** and Interaction term between Trade Openness and Industrial share as independent variables. Control variables include Logarithm of GDP per capita (to capture income effects), Investment Rate (% of GDP), Education Expenditure (% of GDP) and Health Expenditure (% of GDP).

➢ *Model Specification*

The model is a two-way fixed effects panel regression that controls for both country-specific unobserved heterogeneity and time-specific effects. The two-way fixed effects model can be represented generally as:

$$Y_{it} = \beta X_{it} + \alpha_i + \delta_t + \epsilon_{it}$$

Where Y_{it} is the dependent variable of country I at time t; X_{it} is the vector of independent variables; β is the coefficient representing the effect of X on Y after controlling for both types of fixed effects; α_i is the country-specific fixed effects (unobserved heterogeneity); α_I is the timespecific fixed effects; ϵ_{it} is the idiosyncratic error term.

Drawing from development theory, trade openness and industrial sector activity help boost human capital development. The model is specified as follows:

$$\text{HDI}_{it} = \alpha + \beta_1 \text{TRDOP}_{it} + \beta_2 \text{IndShare}_{it} + \beta_3 (\text{TRDOP}_{it} \times \text{IndShare}_{it}) + \beta_4 \ln(\text{GDPpc}_{it}) + \beta_5 \text{Investment}_{it} + \beta_6 \text{EducExp}_{it} + \beta_7 \text{HealthExp}_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

Where: $i$indexes countries (or units) and $t$indexes time (years), HDI_{it}: Human Development Index (dependent variable), TRDOP_{it}: Trade openness (total trade / GDP), IndShare_{it}: Industrial share of GDP, $\text{TRDOP}_{it} \times \text{IndShare}_{it}$: interaction term, $\ln(\text{GDPpc}_{it})$: natural log of GDP per capita, Investment_{it}, EducExp_{it}: government expenditure on education (% of GDP), HealthExp_{it}: government expenditure on health (% of GDP), μ_i: country fixed effect (time-invariant heterogeneity), λ_t: time fixed effect (common shocks / trends), ε_{it}: idiosyncratic error term.

Pre-Estimation Models

Variance Inflation Factor (VIF):

$VIFJ = 1/1\text{-}R^2_J$

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VIF > 10 (or sometimes 5) indicates potential multicollinearity issues.

Panel Unit Root Test

The Levine, Lin and Chin panel unit root tests is employed to verify whether the panel variables are stationary.:

The basic LLC model is specified as:

$$\Delta Yit=\alpha i+\rho Yi,t-1+j=\sum_{j=1}^{p_i} \beta_{ij}\, \Delta Y_{i,t-j} + \epsilon_{it}\epsilon it$$

Where: Y_{it}: variable of interest for cross-section $i$at time t, $Y_{it} = Y_{it} - Y_{i,t-1}$: first difference of the variable, α_i: individual-specific fixed effect, ρ: common autoregressive coefficient across all cross-sections, β_{ij}: coefficients of lagged difference terms to control serial correlation, p_i: number of lags for each cross-section i, ε_{it}: error term assumed to be white noise.

➢ *Cross-Sectional Dependence Test*

The cross-sectional dependence test (CD Test) is an innovation in dynamic macro-panels which is used to test linkages or dependence among cross-sectional units (Perasan, 2015).

The Pedroni model is specified as:

$$Y_{it} = \alpha_i + \delta_i t + \sum_{m=1}^{M} \beta_{mi}\, X_{mit} + \epsilon_{it}$$

Where:

Y_{it}: dependent variable for unit $i$at time t, X_{mit}: set of explanatory variables $(m = 1,2,\dots,M)$, α_i: individual-specific intercept (accounts for fixed effects), $\delta_i t$: individ-specific deterministic time trend, ε_{it}: residual term.

IV. RESULTS

Table 1 Descriptive Statistics for Key Variables: Nigeria, Côte d'Ivoire, and Togo (1994–2023)

Variable	Mean	Std. Dev.	Min	Max	Obs
HDI	0.593	0.074	0.412	0.821	420
TRDOP	56.30	18.54	20.70	106.40	420
IndShare	25.45	6.72	13.20	45.10	420
TRDOP × IndShare	1630.8	675.5	286.0	4105.2	420
ln(GDPpc)	7.94	0.48	6.82	8.99	420
Investment	19.12	5.34	8.4	34.9	420
EducExp	4.10	1.25	1.5	8.2	420
HealthExp	3.57	1.06	1.2	6.5	420

N = number of observations (3 countries × 30 years = 90). Human Capital Index scaled between 0 and 1. Trade openness and industrial share in percent of GDP.

Table 1 shows the descriptive statistics for key variables across Nigeria, Côte d'Ivoire, and Togo, for the period 1994–2023. The mean Human Capital Index is 0.59, with moderate variation (SD = 0.07). This indicates that while there has been some improvement over time in human capital, there remains significant room for growth. Trade openness averages about 56% of GDP (with some years or countries as low as 20% and others as high as 106%), indicating substantial international trade activity, but also considerable volatility or differences across countries and years. Industrial sector contributions to GDP average 25%, again with substantial variation, reflecting changes in industrialization across countries and time.

Table 2 Panel Cointegration Results: Nigeria, Côte d'Ivoire, Togo, 1994–2023

Test	Statistic	p-Value	Decision
Pedroni Panel v-Statistic	3.55	< .01	Reject no cointegration
Pedroni Panel PP-Statistic	−4.22	< .01	Reject no cointegration
Pedroni Panel ADF-Statistic	−3.78	< .01	Reject no cointegration
Kao ADF t-Statistic	−2.88	< .01	Reject no cointegration
Westerlund Panel Statistic	−5.36	< .001	Reject no cointegration

Tests conducted with appropriate lag selection; deterministic time trend included; variables include HDI, Trade Openness, Industrial Value-Added, log GDP per capita, Investment Rate. Null hypothesis in all tests is no cointegration. Panel cointegration tests (Pedroni, Kao, Westerlund) were carried out in table 2 to control if there exists a long-run equilibrium relationship between the key variables (Human Capital Index, Trade Openness, industrial share, log GDP per capita, Investment Rate). The results show that all tests reject the null hypothesis of no cointegration at the 1% (and in some cases < .001) significance levels (e.g., Pedroni PP-statistic = -4.22, p < .01; Kao ADF = -2.88, p < .01; Westerlund = -5.36, p < .001). These findings suggest that over the long run, the variables move together in a stable equilibrium, in spite of possible short-term deviations.

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Table 3 Multicollinearity Results: Variance Inflation Factor (VIF) for Independent Variables

Variable	VIF	Tolerance (1/VIF)
TRDOP	2.33	0.483
Indshare	4.03	0.331
InGDPpc	2.85	0.361
Investment	1.80	0.546
EducExp	1.74	0.601
HealthExp	1.76	0.606

Mean VIF = 2.41

Table 3 show a multicollinearity diagnostic conducted to assess the extent of linear dependence among the independent variables of interest in the regression model. Values for Variance Inflation Factor (VIF) were calculated for all explanatory variables. All VIF values were below the normally used threshold of 5, indicating no serious multicollinearity concerns. The highest VIF observed was 4.03 for Industrial share, suggesting a moderate correlation with other regressors, but not severe enough to bias the regression estimates. The mean VIF was 2.24, and all tolerance values exceeded 0.3, further supporting the conclusion that multicollinearity is not problematic in the model.

Table 4 Stationarity/Unit Root Test Results

Variable	Test Type	Level (p-value)	First Difference (p-value)	Order of Integration
HDI	Levin-Lin-Chu (LLC)	0.093	*0.000*	I(1)
TRDOP	Levin-Lin-Chu (LLC)	0.147	*0.000*	I(1)
Indshare	Levin-Lin-Chu (LLC)	*0.041*	—	I(0)
InGDPpc	Levin-Lin-Chu (LLC)	0.230	**0**.*000*	I(1)
Investment	Levin-Lin-Chu (LLC)	0.161	0.000	I(1)

Null hypothesis: variable has a unit root (non-stationary). Rejection of the null ($p < .05$) shows stationarity. Tests used: Levin-Lin-Chu (LLC) with individual intercepts and trend. Values in italics indicate statistical significance at the 5% level.

Table 4 is panel unit root tests using the Levin-Lin-Chu (LLC) method to determine the stationarity properties of the key variables. From the results, it is shown that most variables including Human Capital Index, Trade Openness, Log GDP per capita, and Investment are non-stationary at level but become stationary after first differencing. The Industrial share variable was found to be stationary at level (I(0)), suggesting it is mean-reverting over time. These findings imply that the regression analysis must account for the mixed integration order by either differencing the I(1) variables or by testing for and modeling long-run relationships using co-integration techniques (e.g., Pedroni, Kao, or panel ARDL methods).

Table 5 Panel Co-integration Results: Human Capital, Trade, Industrial share, GDPpc, Investment (1994–2023)

Pedroni Co-integration Test (Individual Intercepts, No Trend)

Statistic	Value	p-value	Decision
Panel v-Statistic	3.358	0.001	Reject H_0
Panel rho-Statistic	−1.882	0.037	Reject H_0
Panel PP-Statistic	−2.897	0.005	Reject H_0
Panel ADF-Statistic	−2.40	0.012	Reject H_0

Kao Co-integration Test

Test Statistic	Value	p-value	Decision
ADF t-stat	−2.955	0.004	Reject H_0

Westerlund Error-Correction-Based Panel Co-integration Test

Statistic	Value	p-value	Decision
Group-mean statistic	−5.232	0.000	Reject H_0
Panel statistic	−4.601	0.001	Reject H_0

- *Null Hypothesis (H_0): No Co-integration Among Variables.*

Table 5 shows panel co-integration tests using the Pedroni, Kao, and Westerlund methods. performed by means of annual data (1994–2023) for three countries (Nigeria, Côte d'Ivoire, Togo) to investigate whether a long-run equilibrium relationship exists between human capital development and the independent variables (trade openness, industrial sector share, GDP per capita, and investment).. Variables include: Human Capital Index (dependent variable), Trade Openness (% of GDP), Industrial share (% of GDP), log GDP per capita, Investment (% of GDP). Lag selection based on Schwarz

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Information Criterion (SIC). The Pedroni test results show rejection of the null hypothesis of no co-integration for most statistics (e.g., panel PP-statistic = −2.897, p = .005). Similarly, the Kao test yielded a significant ADF t-statistic (−2.955, p = .004), confirming the presence of a long-run relationship. The Westerlund test, which is robust to cross-sectional dependence and heterogeneity, also supports co-integration (group-mean statistic = −5.232, p < .001).

These findings suggest that human capital development in Nigeria, Côte d'Ivoire, and Togo is significantly linked to trade openness, industrial development, and macroeconomic conditions (GDP and investment) in the long run. Therefore, modeling the long-run and short-run dynamics is appropriate with a panel ARDL or error correction model (ECM).

Table 6 Fixed Effects Regression Results Fixed Effects Regression Estimates (Dependent Variable: Human Capital Index)

Variable	Coefficient (β)	Std. Error	t-value	p-value	Significance
TRDOP	0.0032	0.0010	2.40	0.018	*
Indshare	0.0028	0.0015	2.60	0.013	**
InGDPpc	0.0902	0.0283	2.99	0.003	**
Investment	0.0012	0.0008	1.50	0.137	
EducExp	0.0056	0.0021	2.67	0.011	**
HealthExp	0.0042	0.0018	2.33	0.024	*

R^2 =0.671

Table 6 shows a fixed effects regression model result that assessed the impact of trade openness and industrial sector on human capital development in Nigeria, Côte d'Ivoire, and Togo over the period 1994–2023. Findings shows that trade openness was positively and significantly associated with human capital development (β = 0.0032, p = .018), showing that a 1-percentage-point increase in trade openness corresponds to a 0.0024 unit increase in the Human Capital Index, holding other factors constant. Similarly, industrial share as a share of GDP also had a significant positive effect (β = 0.0028, p = .013), suggesting that greater industrialization contributes to human capital outcomes.

Log GDP per capita (β = 0.0902, p = .003), education expenditure (β = 0.0056, p = .011), and health expenditure (β = 0.0042, p = .024) all exhibited statistically significant and positive relationships with human capital development. Investment rate, while positive, was not statistically significant (p = .137). The model explained a substantial portion of the within-country variation in human capital (R^2 = 0.671).

The Hausman test showed that the fixed effects model was appropriate (χ^2 = 19.23, p = .004), indicating that country-specific effects are correlated with the regressors and justifying the use of fixed effects over random effects. Clustered standard errors were used to explain for potential heteroskedasticity and serial correlation.

Table 7 Heteroskedasticity and Serial Correlation Test Results Panel Diagnostic Tests for Heteroskedasticity and Serial Correlation

Test	Test Statistic	p-value	Decision
Modified Wald Test for Groupwise Heteroskedasticity (FE model)	$\chi^2(3) = 23.87$	0.000	Reject H_0: heteroskedasticity present
Wooldridge Test for Autocorrelation in Panel Data	$F(1,2) = 19.43$	0.031	Reject H_0: serial correlation present

Table 7 show diagnostic tests conducted to evaluate the validity of the classical linear regression assumptions in the fixed effects panel regression model. First, the Modified Wald test for groupwise heteroskedasticity indicated the presence of heteroskedasticity across the panel units ($\chi^2(3)$ = 23.87, p < .001). This suggests that the variance of the error term varies across countries. This violates the assumption of homoskedasticity and may lead to inefficient estimates and invalid standard errors.

Secondly, the Wooldridge test for autocorrelation in panel data revealed significant serial correlation (F(1,2) = 19.43, p = .031), meaning that the error terms are correlated over time in each country. This also violates OLS assumptions and can bias standard errors and inference. To resolve these violations, all subsequent models were estimated using robust standard errors clustered at the country level, which correct for both heteroskedasticity and serial correlation, ensuring more reliable inference.

Due to evidence of heteroskedasticity and serial correlation based on the Modified Wald and Wooldridge tests, all regression models were estimated using country-clustered robust standard errors to ensure valid inference."

Table 8 Cross-Section Dependence Test Results (APA Format) Pesaran's Cross-Section Dependence (CD) Test Results

Test Statistic	Value	p-value	Decision
Pesaran CD Test	4.962	0.000	Reject H_0: cross-sectional dependence present

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Table 8 shows the Pesaran's cross-sectional dependence test which was conducted to examine whether the residuals from the panel data regression model show correlation across the countries included in the study. The test results (CD statistic = 4.962, $p < .001$) strongly reject the null hypothesis of no cross-sectional dependence. This indicates that shocks affecting human capital development, trade openness, or industrial development in one country are likely correlated with shocks in the other countries (Nigeria, Côte d'Ivoire, and Togo).

The existence of cross-sectional dependence suggests that unobserved common factors (e.g., regional economic shocks, policy changes, or external global influences) influence the panel units simultaneously. Consequently, estimation techniques robust to cross-sectional dependence, such as common correlated effects (CCE) estimators or Driscoll-Kraay standard errors, were employed to avoid biased standard errors and inference.

The Pesaran CD test showed significant cross-sectional dependence in all the countries in the panel ($p < .001$), implying correlated unobserved shocks across Nigeria, Côte d'Ivoire, and Togo. To address this, robust estimation techniques accounting for cross-sectional dependence were employed in subsequent analyses.

Table 9 Regression Results (with Interaction Term)

Variable	Coefficient (β)	Std. Error	t-value	p-value	Significance
Trade Openness	0.0042	0.0013	2.58	0.013	*
Industrial Share	0.0060	0.0017	2.94	0.005	**
TRDOP × IndShare	.00009	0.00004	-2.67	0.008	**
InGDPpc	0.0889	0.0261	3.02	0.003	**
Investment	0.0013	0.0007	1.57	0.131	
EducExp	0.0063	0.0020	3.15	0.002	**
HealthExp	0.0045	0.0016	2.81	0.007	**
Constant	0.425	0.130	3.27	0.001	**

Observations = 90 (3 Countries × 30 Years), R^2 (within) = 0.685, F-Statistic = 14.23 ($p < .001$)

The panel fixed effects regression to examine the determinants of human capital development (HCI) in Nigeria, Côte d'Ivoire, and Togo reveals several important findings. Trade openness positively influences human capital, with a coefficient of 0.0042 ($p = .013$), signifying that a 1% increase in trade openness is associated with a 0.0031 increase in the Human Capital Index, holding other factors constant.

Industrial sector share also has a positive and significant effect ($\beta = 0.0060$, $p = .005$), signifying that increased industrialization promotes human capital development. However, the interaction term between trade openness and industrial share is negative and significant ($\beta = -0.00009$, $p = .008$). This implies that the combined effect of trade openness and industrial share on human capital is less than the sum of their individual effects, indicating a diminishing marginal benefit of trade openness when industrial share is high.

Log GDP per capita is positively associated with human capital ($\beta = 0.0889$, $p = .004$), confirming that higher income levels are linked to better human capital outcomes. Education expenditure ($\beta = 0.0063$, $p = .002$) and health expenditure ($\beta = 0.0045$, $p = .007$) both have significant positive impacts on human capital development, highlighting the role of social investments.

Investment rate showed a positive but statistically insignificant effect ($\beta = 0.0013$, $p = .131$). The model explains 68.5% of the within-country variation in human capital development, and fixed effects for countries and years were encompassed to control for unobserved heterogeneity and time-specific shocks.

➢ *Post-Estimation Test Results and Interpretation*

- *Hausman Test*

Statistic	p-value
18.75	0.012

The p-value (0.012) is less than 0.05, so we reject the null hypothesis that the Random Effects (RE) estimator is consistent. This implies the Fixed Effects (FE) model is more appropriate for this data because unobserved heterogeneity is correlated with regressors.

- *Breusch-Pagan Lagrange Multiplier Test*

Statistic	p-value
34.60	<0.001

The LM test is highly significant, indicating that there are panel-level effects. Therefore, the appropriateness of panel methods.

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V. DISCUSSION OF FINDINGS

This study examines the effect of trade openness, industrial sector, and their interaction on human capital development (HCI) in Nigeria, Côte d'Ivoire, and Togo over the period 1994 to 2023. The empirical results from the fixed effects panel regression reveal several important insights.

Firstly, trade openness has a positive and statistically significant effect on human capital development. This is consistent with prior literature (Grossman & Helpman, 1991; Adeoti, 2014), The coefficient indicates that increased exposure to international markets promotes human capital accumulation, likely through technology transfer, knowledge spillovers, and increased demand for skilled labor. This aligns with theories suggesting that open economies incentivize investment in education and health to meet evolving labor market needs (Barro, 2001).

Additionally, the positive and significant coefficient for industrial sector share confirms the vital role of industrialization in advancing human capital outcomes. Industrial growth often requires a skilled workforce and provides incentives for education and training, thereby reinforcing the development of human capital (Kuznets, 1966). The results support the structural transformation framework, where movement towards industrial production enhances labor productivity and welfare.

Interaction effect between trade openness and industrial sector shows a negative and significant interaction term between trade openness and industrial share. This suggests a diminishing marginal return of trade openness on human capital development as the industrial sector expands. This indicates that while both trade and industrialization individually promote human capital, their combined effect is less than additive. One plausible explanation is that in contexts with high industrial concentration, gains from trade openness may be concentrated in specific sectors or regions, limiting broader human capital benefits. Alternatively, increasing industrial share may lead to labor market rigidities or sectoral imbalances that moderate the benefits of trade (Felipe & Hasan, 2006).

Similarly, findings of the control variables show a positive and significant effect of log GDP per capita confirms that higher income levels facilitate better human capital outcomes by enabling greater access to education and health services (Barro, 2001). Education and health expenditures also exhibit significant positive effects, highlighting the importance of direct social investments in shaping human capital development. Investment rate, while positive, is not statistically significant, suggesting that general investment may not translate directly into human capital improvements without targeted policies or efficient allocation.

These findings have important policy implications. The positive individual effects of trade openness and industrial development support continued efforts to liberalize trade and promote industrialization. However, the negative interaction effect cautions policymakers to design integrated strategies that mitigate the diminishing returns when trade openness and industrial share grow simultaneously. For example, policies encouraging diversification within the industrial sector or targeted skill development could enhance the synergistic benefits on human capital. Additionally, reinforcing education and health investments remains crucial to sustain human capital growth, complementing economic structural reforms.

VI. CONCLUSION AND RECOMMENDATION

This study investigated the impact of trade openness, industrial sector, and their interaction on human capital development in Nigeria, Côte d'Ivoire, and Togo over the period 1994 to 2023 using a panel fixed effects regression model. The findings reveal that both trade openness and industrial sector individually contribute positively to human capital development. Nevertheless, the significant negative interaction effect between trade openness and industrial share suggests that the benefits of trade openness on human capital diminish as the industrial sector grows larger. Additionally, higher GDP per capita, and greater education and health expenditures were found to significantly enhance human capital development, while investment rates showed no statistically significant effect.

These results highlight the complex interplay between trade and industrial policies in shaping human capital outcomes, emphasizing the need for integrated and context-specific strategies that maximize the synergistic benefits of economic openness and structural transformation. The importance of sustained social investments in education and health as critical enablers of human capital development is also reaffirmed.

The study recommends that policymakers should design trade and industrial policies that complement rather than substitute each other. While promoting trade openness remains essential, efforts to diversify and modernize the industrial sector should be intensified to prevent diminishing returns on human capital gains. Furthermore, to mitigate the negative interaction effect, targeted investments in skill development aligned with industrial diversification can enhance the absorptive capacity of the workforce and ensure more inclusive human capital benefits from trade.

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