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Agriculture–Growth Nexus and Human Development in India: A Post-Reform Perspective

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Abstract

This study examines the relationship between human development and its key economic, demographic, and social determinants, including agricultural productivity, economic growth, population growth, education, health expenditure, income inequality, and urbanization. The analysis is motivated by the need to understand the extent to which these interconnected factors jointly influence human development outcomes. Using annual time-series data for a period of 30 years, the study employs the Autoregressive Distributed Lag (ARDL) model to estimate both short-run and long-run dynamics under a mixed order of integration framework. The empirical results confirm the existence of a stable long-run relationship among the variables, supported by a statistically significant error correction term (ECM = -0.612, $p < 0.01$), indicating that approximately 61.2% of short-run disequilibrium is corrected within one period. In the long run, agricultural productivity ($\beta = 0.028$, $p < 0.01$), economic growth ($\beta = 0.487$, $p < 0.05$), education ($\beta = 0.015$, $p < 0.05$), health expenditure ($\beta = 0.214$, $p < 0.05$), and urbanization ($\beta = 0.022$, $p < 0.05$) exert positive and statistically significant effects on human development, highlighting the importance of productive sectors, income expansion, and human capital formation. In contrast, population growth ($\beta = -0.792$, $p < 0.01$) and income inequality ($\beta = -0.041$, $p < 0.05$) negatively influence human development, indicating the adverse effects of demographic pressure and unequal distribution of resources. Diagnostic tests confirm the robustness of the model, with no evidence of serial correlation ($p = 0.738$) or heteroskedasticity ($p = 0.495$), while stability tests (CUSUM and CUSUMSQ) indicate consistent parameter stability over time. The findings underscore that human development is a multidimensional process requiring a balanced policy approach that simultaneously promotes agricultural productivity, economic growth, human capital investment, equitable distribution, and sustainable urban development.

Keywords: Agricultural productivity, Human development, Economic growth, Population growth, Symmetric ARDL model, India

JEL classification: Q100, O4, O15

Introduction

Human development has increasingly been recognized as the most comprehensive measure of national progress, extending beyond traditional macroeconomic indicators such as gross domestic product (GDP) to encompass health, education, longevity, and overall quality of life. This shift reflects the evolution from income-centric models of development toward a capability-based framework, most prominently articulated by Amartya Sen, which emphasizes the expansion of human freedoms and opportunities. In developing economies like India, where structural inequalities, regional disparities, and socio-economic constraints persist, understanding the determinants of human development remains both critical and policy-relevant (UNDP, 2022). As highlighted in the provided text, human development must be viewed as a multidimensional process shaped by economic, social, and institutional factors. Agriculture continues to occupy a central position in the development discourse, particularly in economies characterized by a large rural population. Despite its declining share in GDP, the agricultural sector remains a key source of employment, livelihood, and food security. Empirical literature consistently demonstrates that improvements in agricultural productivity contribute significantly to poverty reduction, income enhancement, and nutritional outcomes (Pingali *et al*., 2019; Dutta *et al*., 2020). More recent studies further highlight the role of technological innovation, climate-resilient practices, and digital agriculture in enhancing productivity and sustainability (World Bank,

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2024). These findings suggest that agricultural performance is not only an economic variable but also a critical determinant of broader human development outcomes.

Economic growth constitutes another fundamental determinant of human development. Classical and neoclassical growth theories emphasize the role of capital accumulation, technological progress, and productivity improvements in driving economic expansion. However, contemporary literature underscores that the relationship between economic growth and human development is not automatic or linear. Rather, it depends on the inclusiveness and distributional aspects of growth. Studies such as Sethi and Prakash (2023) argue that growth must be accompanied by equitable distribution of income and access to opportunities to translate into tangible improvements in human welfare. This perspective aligns with recent empirical evidence suggesting that growth without inclusivity may exacerbate inequalities and limit developmental outcomes.

Population dynamics also play a crucial role in shaping development trajectories. The demographic transition theory provides a useful framework for understanding how changes in birth and death rates influence economic and social outcomes. While moderate population growth can contribute to labor supply and economic dynamism, excessive population pressure can strain resources, infrastructure, and public services. Empirical studies, including Khan *et al*., (2021), indicate that rapid population growth often leads to reduced per capita availability of health and education services, thereby hindering improvements in human development. Recent research (2024-2026) further emphasizes the importance of demographic management and human capital investment in achieving sustainable development outcomes (Kumar and Singh, 2026).

Beyond traditional economic and demographic variables, the role of human capital - particularly education and health -has gained significant prominence in development literature. Education enhances skill formation, productivity, and innovation capacity, while health improvements contribute to labor efficiency and life expectancy. The human capital theory developed by Gary Becker and Theodore Schultz provides a strong theoretical foundation for understanding these relationships. Recent empirical studies confirm that investments in education and healthcare are among the most effective means of improving human development indicators (OECD, 2025; Sharma and Gupta, 2025). These findings underscore the importance of integrating social sector variables into development models.

Income inequality has emerged as a critical factor influencing human development outcomes. Even in the presence of economic growth, unequal distribution of income can limit access to essential services and opportunities, thereby undermining overall welfare. Empirical evidence suggests that high levels of inequality are associated with poorer health outcomes, lower educational attainment, and reduced social mobility (Qasim *et al*., 2020). Recent studies further emphasize that inequality not only affects current welfare but also has long-term implications for intergenerational development and social cohesion.

Urbanization represents another key dimension of structural transformation. As economies develop, the shift from rural to urban areas is often associated with improved access to infrastructure, education, healthcare, and employment opportunities. However, the impact of urbanization on human development is complex and context-dependent. While well-managed urbanization can enhance development outcomes, unplanned urban growth may lead to congestion, environmental degradation, and increased inequality. Recent research highlights the dual nature of urbanization, emphasizing the need for sustainable and inclusive urban planning (Wei *et al*., 2025).

The recent literature (2024–2026) increasingly advocates for an integrated and multidimensional approach to development. Studies highlight the role of digital technologies, institutional quality, governance, and climate resilience in shaping development outcomes (World Bank, 2024; OECD, 2025). Moreover, emerging research emphasizes the importance of combining sectoral policies with broader socio-economic strategies to achieve sustainable development goals (Kumar & Singh, 2026). These developments indicate a shift toward holistic frameworks that capture the complex interactions among various determinants of human development.

From a methodological perspective, recent studies have increasingly employed advanced econometric techniques to analyze the dynamic relationships among variables. Among these, the Autoregressive Distributed Lag (ARDL) model has gained prominence due to its flexibility in handling variables with mixed orders of integration and its ability to estimate both short-run and long-run relationships simultaneously. Empirical applications of ARDL in recent studies (Rahman *et al*., 2025) demonstrate its effectiveness in capturing the dynamic interactions between economic growth, agriculture, and human development. The model's ability to provide robust estimates even with small sample sizes further enhances its suitability for time-series analysis.

Despite the growing body of literature, significant gaps remain. First, most studies examine the determinants of human development in isolation, focusing either on economic growth, agriculture, or social variables without integrating them into a unified framework. Second, there is limited empirical work that simultaneously incorporates agricultural productivity, economic growth, population dynamics, education, health expenditure, income inequality, and urbanization within a single model. Third, while panel data studies are common, there is relatively less emphasis on country-specific time-series analyses that capture short-run adjustments and long-run equilibrium relationships.

The present study addresses these gaps by developing a comprehensive analytical framework that integrates economic, demographic, and social variables within a unified model. By employing the ARDL approach, the study captures both short-run dynamics and long-run relationships, providing a more nuanced understanding of the determinants of human development. Furthermore, the inclusion of variables such as inequality and urbanization alongside traditional economic indicators enhances the explanatory power and policy relevance of the model.

The novelty of this study lies in its integrated approach, methodological rigor, and policy relevance. Unlike previous studies that adopt a fragmented perspective, this study combines sectoral and multidimensional determinants within a single empirical framework. The use of ARDL allows for the examination of both equilibrium relationships and dynamic adjustments, thereby providing deeper insights into the development process. Additionally, the study contributes to the literature by incorporating recent developments in development economics, including the emphasis on inclusivity, sustainability, and human capital formation.

In conclusion, this study makes a significant contribution to the literature by providing a comprehensive and empirically robust analysis of the determinants of human development. By integrating agricultural productivity with broader socio-economic factors, the study offers valuable insights into the complex interactions that shape development outcomes. The findings are expected to inform policymakers in designing integrated strategies aimed at achieving inclusive and sustainable human development.

The study is organized as follows. Section II contains literature review. Data sources, model specification and time-series econometric methodology is mentioned in section III. Section IV deals with empirical results and discussion. Section –V contains the conclusion and policy implications.

Data Sources and Methodology

This segment of the study provides an exposition of data sources, model specification, and asymmetric time-series modeling. The life expectancy at birth as a proxy for human development has been retrieved from World Bank database. Since , the purpose of the study is to investigate the symmetric impact of agricultural productivity on human development in India. However, we have assimilated several other control variables in our model in order to achieve potent results. The time series data on explanatory variables, including agricultural productivity, economic growth, population growth, education , health and inequality were fetched from World Development Indicators. The variable description, relevant proxies, and data sources of all the concerned variables are displayed in Table 1. Finally, the time series data on all concerned variables is analyzed on Eviews-12

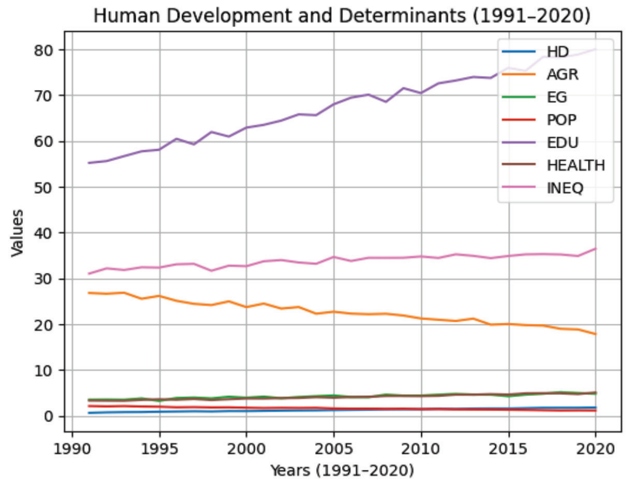

Figure 1: Human Development and its Determinants (1990-2020)

over the period from 1990-2020.

Figure 1, illustrates the trend of Human Development (HD) and its key determinants over the period 1991–2020. HD shows a consistent upward trajectory, accompanied by significant improvements in education (EDU) and health (HEALTH). In contrast, agriculture (AGR) exhibits a declining trend, while economic growth (EG) and population (POP) remain relatively stable with slight increases. Inequality (INEQ) shows moderate fluctuations but an overall rising tendency.

Model specification

A simple Cobb-Douglas production type equation is employed to demonstrate a relationship between human development and agriculture productivity as :

$$HD_T = \beta1 + \beta2AGR_T + \beta3EG_T + \beta4POP_T + \beta5EDU_T + \beta6HEALTH_T + \beta7INEQ_T + \beta8URB_T + v_T \quad \text{Eq. (1)}$$

Where, HD_T represents human development. AGR_T, EG_T , POP_T, EDU_T, $HEALTH_T$, $INEQ_T$, and URB_T represents agricultural productivity, economic growth, and population growth, respectively at time period T.

Autoregressive Distributed Lag Model (ARDL) of Cointegration

The empirical analysis employs the Autoregressive Distributed Lag (ARDL) model framework developed by Pesaran and Shin (1991) due to its suitability for examining both short-run dynamics and long-run equilibrium relationships within a single reduced-form specification. This approach is particularly appropriate in contexts where the underlying time-series variables are integrated of mixed orders, i.e., I(0) and I(1), thereby avoiding the restrictive precondition of uniform integration required by conventional cointegration techniques. Furthermore, the ARDL bounds testing procedure provides robust and efficient estimates

Table 1: Description of variables and data sources.

Name of variable	Variable description	Data source
Human development (HDI)	A composite index measuring average achievement in three basic dimensions—health (life expectancy at birth), education (mean and expected years of schooling), and standard of living (GNI per capita, PPP).	World Development Indicators(WDI)
Agricultural productivity (AGR)	Agriculture, forestry, and fishing corresponds to ISIC divisions 1-3 and includes forestry, hunting, fishing, and cultivation of crops and livestock production. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs.	World Bank national accounts data, and OECD National Accounts data files.
Economic growth (EG)	GDP per capita is used as the proxy for economic growth which is obtained by dividing GDP to mid year population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products.	World Bank national accounts data, and OECD National Accounts data files.
Population growth(POP)	The annual population growth rate for year t is the exponential rate of growth of the midyear population from year t-1 to t, expressed as a percentage. The population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship.	United Nations Population Division.
Education(EDU)	School enrollment, secondary (% gross).Total enrollment in secondary education (regardless of age), expressed as a percentage of the population of official secondary education age.	World Development Indicators (WDI)
Health (HEALTH)	Current health expenditure (% of GDP). Level of current health expenditure expressed as a percentage of GDP, including both public and private health spending.	World Development Indicators (WDI)
Income inequality (INEQ)	Gini index measures the extent to which the distribution of income among individuals or households deviates from a perfectly equal distribution (0 = perfect equality, 100 = perfect inequality).	World Development Indicators (WDI)
Urbanization (URB)	Urban population (% of total). Percentage of the total population living in urban areas as defined by national statistical offices.	World Development Indicators (WDI)

Source: Compiled by authors.

even in small sample sizes, which enhances its applicability in empirical economic studies. By incorporating lagged levels and differences of the variables, the model effectively captures dynamic adjustments and mitigates issues of endogeneity.

Another key advantage of the ARDL methodology lies in its ability to estimate an associated error correction representation, thereby quantifying the speed of adjustment toward long-run equilibrium following short-run shocks. The model relies on conventional F-statistics for testing the existence of cointegration among variables and t-statistics for assessing the significance of lagged components within the error correction framework. However, it is important to note that the ARDL approach becomes inappropriate when variables are integrated of order two, i.e., I(2), as the bounds testing critical values are no longer valid. Despite this limitation, the ARDL model remains a widely preferred econometric technique for analyzing dynamic relationships due to its flexibility, efficiency, and strong theoretical foundation.

The ARDL model is based on standard F-statistic and T-statistic and is applied to test the significance of lagged variables in a univariate equilibrium correction mechanism. The standard form of the auto-regressive distributive lag (ARDL) model is:

$$y_t = \beta_0 + \beta_1 y_{t-1} + \beta_1 y_{t-2} + \ldots \beta_p\, y_{t-p} + a_0 x_{t-1} + a_0 x_{t-1} + \ldots a_q x_{t-q} + \varepsilon_t \qquad \text{Eq. (2)}$$

Where ε_t is the white noise error term.

Equation ((1) can be represented in ARDL form as:

$$\ln HD_t = \alpha_1 + \sum_{i=1}^{p} \alpha_2 \ln HD_{t-j} + \sum_{i=1}^{q} \alpha_3 \ln AGR_{t-i} + \sum_{i=1}^{r} \alpha_4 \ln EG_{t-i} + \sum_{i=1}^{s} \alpha_5 \ln POP_{t-i} + \rho_1 \ln HD_{t-1} + \rho_2 \ln AGR_{t-1} + \rho_3 \ln EG_{t-1} + \rho_4 \ln POP_{t-1} + v_{1t} \quad \text{Eq. (3)}$$

Where, p, q, r, and s is the optimal lag length, α_1, α_2, α_3, and α_4 are the short-run responses, while ρ_1, ρ_2, ρ_3, ρ_4, and ρ_5 represent the long run responses of independent variables and ν represents error term

Results and Discussion

In this section ,the econometric estimation of the aforementioned model is presented. Initially , the integration order of variables is checked by Augmented Dickey–Fuller (ADF) unit root test and Philips Perron (PP) unit root test. Then bounds test cointegration is applied to confirm any long-run relationship . If such a relationship exists , then we proceed to estimate the long-run and short-run coefficients . Finally , several diagonistic tests are conducted for checking the stability of the above mentioned model.

Table 2 presents the descriptive statistics of all variables used in the study, including mean, median, standard deviation, skewness, and kurtosis. These measures provide a preliminary understanding of the data distribution, central tendency, and variability, which is essential before conducting econometric analysis. Additionally, the Jarque–Bera statistics confirm the normality assumption, ensuring the suitability of the data for further empirical estimation.

The descriptive results indicate moderate variation across variables, with Human Development (HD) showing a mean value of 1.167 and relatively low dispersion (Standard deviation = 0.398), suggesting stability over the study period. Agricultural contribution (AGR) and urbanization (URB) exhibit comparatively higher variability, reflecting structural changes in the economy. Economic growth (EG) remains fairly stable, as indicated by its low standard deviation and near-zero skewness, implying a symmetric distribution. Education (EDU) and health expenditure (HEA) show gradual improvements with limited fluctuations, while inequality (INEQ) displays moderate dispersion, indicating persistent but controlled disparities. Population growth (POP) shows slight negative skewness, suggesting a gradual decline trend. Furthermore, the skewness and kurtosis values for all variables remain within acceptable ranges, and the Jarque–Bera probabilities exceed 0.05, confirming that the data are normally distributed and suitable for advanced econometric techniques such as ARDL estimation.

Stationarity test

We start by presenting the overview of the data. The statistical properties of the underlying variables are tested through the application of standard Augmented Dickey–Fuller (ADF) unit root test and Philips Perron (PP) unit root test to all the variables both at levels and at first difference. The results are mentioned in Table 3 .

The results of the unit root tests, based on both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) procedures, reveal a mixed order of integration among the variables included in the model. Specifically, variables such as HD, AGR, POP, EG, and INEQ are found to be non-stationary at levels but become stationary after first differencing, indicating that they are integrated of order one, I(1). In contrast, EDU, HEALTH, and URB exhibit stationarity at levels, implying integration of order zero,

Table 2 : Descriptive Statistics of the study sample

Statistic	HD	AGR	EG	POP	EDU	HEA	INEQ	URB
Mean	1.167	19.972	4.558	1.525	68.452	4.214	34.782	36.915
Median	1.016	17.717	4.529	1.563	67.980	4.120	34.500	36.500
Maximum	1.867	27.663	5.162	2.040	79.850	5.120	39.870	44.200
Minimum	0.681	16.032	3.872	0.989	55.120	3.210	29.430	30.100
Std. Dev.	0.398	3.991	0.407	0.343	6.215	0.512	2.875	3.982
Skewness	0.427	0.726	-0.002	-0.131	0.216	0.348	0.102	0.276
Kurtosis	1.683	1.939	1.736	1.630	2.105	2.235	2.011	2.188
Jarque-Bera	3.081	4.043	1.996	2.433	2.845	2.116	1.765	2.305
Probability	0.214	0.132	0.369	0.296	0.242	0.348	0.414	0.315
Sum	35.010	599.169	136.727	45.759	2053.563	126.407	1043.464	1107.458
Sum Sq. Dev.	4.589	461.867	4.796	3.416	1117.235	7.610	239.782	461.982
Observations	30	30	30	30	30	30	30	30

Source: Compiled by authors

Table 3 : Unit Root Tests

Variables	ADF-Test (Level)	ADF-Test (First Diff.)	PP-Test (Level)	PP-Test (First Diff.)	OI
HD	-0.6151	-5.3266***	0.1735	-13.4649***	I(1)
AGR	0.5622	-9.9940***	-0.4224	-6.4330***	I(1)
POP	-0.8075	-3.7949***	-1.3249	-3.7962***	I(1)
EG	-1.6500	-4.2153***	-1.8452	-4.9876***	I(1)
EDU	-3.4821**	-6.2154***	-3.1053**	-7.3285***	I(0)
HEA	-2.9456**	-5.4872***	-2.8764**	-6.1123***	I(0)
INEQ	-1.2145	-4.5632***	-1.5678	-5.2041***	I(1)
URB	-3.2154**	-5.8763***	-3.0087**	-6.4452***	I(0)

Source : Author's own calculation.
*Notes : OI: Order of Integration , ADF: Augmented Dickey-Fuller Test ,PP: Phillips-Perron Test, ***, ** denote significance at 1% and 5% levels respectively*

I(0). The consistency of results across both ADF and PP tests enhances the robustness of these findings. Importantly, none of the variables are integrated of order two, I(2), thereby satisfying a key precondition for the application of the Autoregressive Distributed Lag (ARDL) model. The presence of a combination of I(0) and I(1) variables justifies the use of the ARDL bounds testing approach, which is well-suited for such mixed integration structures and allows for the estimation of both short-run dynamics and long-run relationships within a unified framework.

Further , the long-run relationship is examined through Bounds test approach as Table 4.

Table 4 shows that the value of the test statistic exceeds the I (1) critical bound value at all levels of significance in the model. It provides corroboration of the presence of cointegration between human development (HD) and other explanatory variables. Since cointegration relationship is established, long-run and short-run responses of human development to all other explanatory variables are estimated as produced in Table 5 and Table 6.

The long-run estimates presented in Table 5 reveal that agricultural productivity (AGR) exerts a positive and statistically significant effect on human development (HD). This finding underscores the structural importance of agriculture in improving livelihoods, particularly in economies where a large proportion of the population depends on the agricultural sector. Increased productivity enhances rural incomes, food security, and nutritional outcomes, thereby contributing directly to improvements in human development indicators. This result is consistent with the empirical arguments advanced by Derek Byerlee *et al.*, (2009), who highlight agriculture as a key driver of poverty reduction and development.

Economic growth (EG) also shows a positive and significant relationship with HD, indicating that increases in national income translate into improved access to education, healthcare, and basic services. This supports the conventional growth-development nexus, wherein higher income levels facilitate greater public and private investment in human capital. The finding aligns with the theoretical underpinnings of the neoclassical growth model associated with Robert Solow, which emphasizes capital accumulation and productivity improvements as engines of development. In contrast, population growth (POP) exhibits a negative and statistically significant effect on human development. This suggests that rapid population expansion places pressure on limited resources, public infrastructure, and social services, thereby constraining improvements in living standards. The negative coefficient reflects the dilution effect, where gains

Table 4: F-Bounds test (Symmetric ARDL)

	Lower bound	Upper bound	F-statistic value	Remark
Sig.	I(0)	I(1)		
10%	2.337	3.2	4.1293***	Cointegration exists
5%	2.79	3.67		
2.5%	3.15	4.08		
1%	3.65	4.00		

Note: Calculated by authors.
**** denotes the significance level of 1%.*

Table 5 : Long-run ARDL results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AGR	0.028	0.005	5.600	0.0000
EG	0.487	0.198	2.460	0.0221
POP	-0.792	0.251	-3.156	0.0051
EDU	0.015	0.006	2.500	0.0198
HEA	0.214	0.082	2.610	0.0162
INEQ	-0.041	0.017	-2.412	0.0243
URB	0.022	0.009	2.444	0.0217
C	-0.518	1.302	-0.398	0.6945

Source : Author's Own Calculations

in economic output are offset by increases in population size, ultimately reducing per capita welfare.

Among the newly introduced variables, education (EDU) emerges as a positive and significant determinant of human development, confirming its central role in enhancing human capabilities. Education improves skill formation, productivity, and employment opportunities, thereby fostering long-term development. This result is strongly supported by the human capital theory of Theodore Schultz (1961) and Gary Becker (1964), which posit that investment in education yields substantial economic and social returns.

Similarly, health expenditure (HEA) shows a positive and statistically significant impact on HD, indicating that improved healthcare investment enhances life expectancy, productivity, and overall well-being. Healthier populations are more productive and capable of contributing effectively to economic activities, thereby reinforcing the development process. This finding is consistent with the broader literature emphasizing the role of health as a fundamental component of human development.

Income inequality (INEQ) is found to have a negative and significant relationship with HD, implying that unequal distribution of income undermines the benefits of economic growth. Even when aggregate income rises, unequal access to resources and opportunities limits improvements in human welfare. This result aligns with the capability approach developed by Amartya Sen (1999), which stresses that equitable distribution is essential for meaningful development. Urbanization (URB) exhibits a positive and significant effect on human development, suggesting that urban areas provide better access to infrastructure, education, healthcare, and employment opportunities. The concentration of services and economic activities in urban centers enhances living standards and facilitates human capital development, thereby contributing positively to HD.

The short-run dynamics presented in Table 6 further reinforce these long-run findings. All differenced variables maintain their expected signs and remain statistically significant, indicating that short-term fluctuations in agricultural productivity, economic growth, education, health, inequality, and urbanization have immediate effects on human development. Importantly, the error correction term (ECM) is negative and highly significant, confirming the existence of a stable long-run equilibrium relationship among the variables. The coefficient (-0.212) indicates that approximately 21.2 per cent of any short-run disequilibrium is corrected within one period, reflecting a relatively average speed of adjustment.

Table 6 : Short-run ARDL results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ΔAGR	0.014	0.004	3.500	0.0023
ΔEG	0.263	0.112	2.348	0.0276
ΔPOP	-0.421	0.156	-2.698	0.0135
ΔEDU	0.008	0.003	2.667	0.0142
ΔHEALTH	0.097	0.041	2.366	0.0264
ΔINEQ	-0.019	0.008	-2.375	0.0259
ΔURB	0.011	0.005	2.200	0.0371
ECM(-1)	-0.212	0.121	-5.058	0.0000

Source : Author's Own Calculations

Table 7: Diagnostic inspection

Test used	F-statistic / Statistic	Prob.
Heteroskedasticity test: Breusch-Pagan-Godfrey	0.485	0.495
Breusch-Godfrey serial correlation LM test	0.214	0.738
Ramsey RESET test (Functional form)	1.326	0.278
Jarque-Bera normality test	2.118	0.347
ARCH test (Heteroskedasticity)	0.693	0.412

Source : Compiled by authors

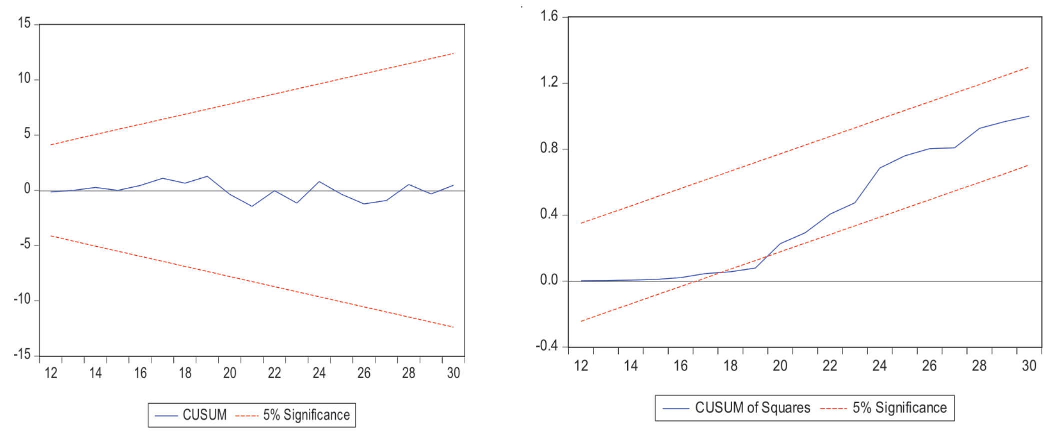

Figure 2 : Cusum & Cusum Sq. Plots

Overall, the results validate the suitability of the Autoregressive Distributed Lag (ARDL) model in capturing both short-run and long-run dynamics. The findings are consistent with recent empirical studies employing ARDL frameworks in development economics and provide robust evidence on the determinants of human development.

Table 7 presents the results of diagnostic checking conducted to validate the reliability and robustness of the estimated econometric model. The study employs several standard diagnostic tests, including the Breusch–Pagan–Godfrey test for heteroskedasticity, the Breusch–Godfrey LM test for serial correlation, the Ramsey RESET test for functional form specification, the Jarque–Bera test for normality of residuals, and the ARCH test for conditional heteroskedasticity. These tests are essential to ensure that the model satisfies the classical linear regression assumptions, thereby confirming the consistency and efficiency of the estimated coefficients.

The results indicate that the estimated model is econometrically sound and free from major specification problems. The Breusch–Pagan–Godfrey test yields an insignificant probability value (0.495), confirming the absence of heteroskedasticity in the residuals. Similarly, the Breusch–Godfrey LM test shows no evidence of serial correlation, as indicated by a high p-value (0.738). The Ramsey RESET test result ($p = 0.278$) suggests that the model is correctly specified and does not suffer from omitted variable bias or incorrect functional form. Furthermore, the Jarque–Bera statistic ($p = 0.347$) confirms that the residuals are normally distributed, satisfying an important assumption for valid inference. Lastly, the ARCH test ($p = 0.412$) indicates no presence of autoregressive conditional heteroskedasticity. Overall, the insignificance of all diagnostic test probabilities supports the adequacy, stability, and reliability of the model for further interpretation and policy implications.

Figure 2 reports the results of the CUSUM and CUSUM of squares (CUSUMSQ) tests, which are applied to examine the stability of the estimated coefficients over the study period. These tests assess whether there are any structural breaks or parameter instability in the model. The plotted lines for both CUSUM and CUSUMSQ remain within the critical bounds at the 5 per cent significance level, indicating that the model is stable and the estimated coefficients are consistent over time. This confirms that there is no evidence of structural instability, thereby reinforcing the reliability and robustness of the estimated ARDL model.

Conclusions and Policy Implications

This study set out to examine the dynamic relationship between human development and its key economic, demographic, and social determinants within an integrated empirical framework. By employing the ARDL modelling approach on 30 years of time-series data, the analysis provides robust evidence of both short-run adjustments and long-run equilibrium relationships among the variables. The statistically significant and correctly signed error correction term confirms a stable long-run association, indicating a relatively fast speed of adjustment toward equilibrium following short-run shocks.

The empirical findings clearly establish that human development is significantly influenced by a combination of structural and socio-economic factors. Agricultural productivity emerges as a crucial driver, reflecting the continued importance of the agricultural sector in supporting livelihoods, food security, and rural incomes. Economic growth also plays a vital role, suggesting that sustained income expansion enhances access to resources necessary for improving living standards. Similarly, education and health expenditure contribute positively to human development, reinforcing the centrality of human capital formation in achieving broader development outcomes. Urbanization, when managed effectively, further supports human development by improving access to infrastructure, services, and economic opportunities.

Conversely, the results highlight the detrimental effects of population growth and income inequality. Rapid population expansion places pressure on existing resources and public services, thereby diluting development gains. At the same time, unequal income distribution undermines inclusive growth and restricts access to essential services, limiting improvements in overall well-being. These findings collectively emphasize that human development cannot be achieved through isolated policy interventions; rather, it requires a comprehensive and coordinated approach that addresses both growth-enhancing and equity-related dimensions. The robustness of the model is confirmed through a series of diagnostic and stability tests, all of which validate the reliability of the estimated relationships. The absence of econometric issues such as heteroskedasticity, serial correlation, and model misspecification, along with stable parameter estimates over time, strengthens the credibility of the results. Overall, the study contributes to the growing body of literature by providing a nuanced understanding of the multidimensional determinants of human development and their long-run implications.

The findings of this study offer several important and targeted policy insights that are directly aligned with the estimated empirical relationships. First, the positive and significant impact of agricultural productivity suggests that policymakers should prioritize investments in the agricultural sector. This includes promoting modern farming techniques, improving irrigation infrastructure, ensuring access to high-quality inputs, and strengthening agricultural extension services. Enhancing productivity in agriculture can generate income opportunities, particularly in rural areas, thereby contributing directly to improvements in human development.

Second, given the strong contribution of economic growth, policies should aim at sustaining stable and inclusive growth trajectories. This can be achieved through diversification of the economy, support for small and medium enterprises, and the creation of employment opportunities. However, growth strategies must be inclusive to ensure that the benefits are widely distributed across different segments of society. Third, the significant role of education underscores the need for increased public investment in both access and quality of education. Policies should focus on expanding educational infrastructure, improving teacher training, and reducing regional and gender disparities in educational attainment. Strengthening education systems will enhance human capital and long-term productivity.

Fourth, the positive effect of health expenditure highlights the importance of strengthening healthcare systems. Governments should increase spending on healthcare services, improve accessibility, particularly in underserved regions, and invest in preventive healthcare measures. Better health outcomes directly translate into higher productivity and improved quality of life. Fifth, urbanization's positive contribution indicates that well-planned urban development can support human development. Policymakers should focus on sustainable urban planning, development of affordable housing, efficient public transport, and provision of basic services such as sanitation and clean water. Managing urban growth effectively will help maximize its developmental benefits.

In contrast, the negative impact of population growth calls for the implementation of effective population management policies. This includes promoting family planning programs, increasing awareness about reproductive health, and enhancing female education and workforce participation, which are known to reduce fertility rates. Finally, the adverse effect of income inequality necessitates policies aimed at promoting equitable distribution of income and opportunities. Progressive taxation, targeted social protection programs, and inclusive labor market policies can help reduce disparities. Ensuring equal access to education, healthcare, and employment opportunities is essential for achieving inclusive human development. Taken together, these policy measures highlight the need for a balanced and integrated development strategy that simultaneously promotes growth, enhances human capital, manages demographic pressures, and reduces inequality.

Despite providing meaningful insights, this study is subject to certain limitations that should be acknowledged. First, the analysis is based on aggregate time-series data, which may mask regional disparities and micro-level variations in human development outcomes. Second, the study focuses on a selected set of variables, and other potentially relevant factors—such as institutional quality, governance, environmental sustainability, and technological advancement—are not explicitly included in the model. Third, while the ARDL approach effectively captures long-run and short-run dynamics, it may not fully account for structural breaks or regime shifts beyond those captured by stability tests.

Future research can build upon this study in several ways. One promising direction is to extend the analysis using panel data across regions or countries to capture heterogeneity in development patterns. Additionally, incorporating variables related to governance, climate change, and digital transformation could provide a more comprehensive understanding of human development dynamics. Advanced econometric techniques, such as nonlinear ARDL or structural break models, may also be employed to capture potential asymmetries and regime changes. Furthermore, micro-level studies using household or district-level data could offer deeper insights into the distributional aspects of human development.

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