

Determinants of Industrial Sector Performance in India: An Empirical and Analytical Study

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Abstract

This study investigates the long run and short run determinants of industrial sector growth in India using the Autoregressive Distributed Lag (ARDL) bounds testing approach. Annual time series data for the period of 1976 to 2024 have been employed to analyze the key macro-economic factors that influence industrial sector performance. The study first examines the stationary properties of the variables using the Augmented Dicky-Fuller (ADF) and Phillips-Perron unit root test. The results indicate that the variables are integrated at a mixed order, $I(0)$ and $I(1)$ and ARDL bounds test confirms the existence of a long-run cointegrating relationship among industrial output and its determinants. The findings shows that gross capital formation, exports of goods and services and inflation have positive and statistically significant impact on industrial sector growth in the long run while foreign direct investment and population are insignificant factors. The short run dynamics estimated through the Error Correction Model (ECM) indicate that the error correction term is negative and statistically significant. Diagnostic tests such as Breusch-Godfrey LM, Breusch-Pagan/Cook-Weisberg, White test for heteroscedasticity, Skewness/Kurtosis (joint), Jarque-Bera (JB) and Ramsey RESET have been performed which confirms the robustness of the results derived from ARDL estimation. Further, the finding of CUSUM and CUSUMSQ indicates that the estimated coefficients are structurally stable and no significant parameter instability occurred during the study period.

Key words: Industrial sector, capital formation, Exports, FDI, ECM, ARDL Bound

Introduction

Industrial sector is widely regarded as a prime engine of economic growth and structural transformation for both developed and developing nations. Countries with strong industrial base tend to experience higher productivity and income growth, promotes international trade, improve technological innovation and facilitate greater employment opportunities. Rostow (1960) argued that industrialization is essential for economic takeoff and long term development. The industrial sector contribution is highly important for the rapid growth of Gross Domestic Product (GDP) of any country and serves as a catalyst for sustainable economic development. Kaldor (1967) emphasized manufacturing as the engine of economic growth as the production in this sector is subject to its increasing returns to scale.

India presents an important case for examining the determinants of industrial sector growth because of its unique development trajectory. Presently, the industrial sector remains one of the major contributors to India's Gross Domestic Product (GDP), regional development, employment generation, international trade and technological advancement. Manufacturing alone contributes approximately 16 to 17% of India's GDP and support millions of jobs across various industries including automobiles, pharmaceuticals, chemicals, electronics, textiles and engineering goods. The initiatives from government such as Make in India, Production Linked Incentives (PLI) schemes, digital India and industrial corridor projects have further

emphasized the importance of industrial development in achieving sustainable economic growth (IBEF-2026).

At the time of independence India inherited an underdeveloped and weak industrial structure characterized by a narrow manufacturing base, limited technological capability, low capital formation and heavy dependence on imports for machinery and industrial goods. Since then over the subsequent decades, the industrial sector evolved through different phases – from state led industrialization and import substitution to globalization, liberalization and technological modernization. First phase of industrial development in India starts from 1947 and lasted up to 1964, better known as Nehruvian period. These years after independence were characterized by optimism and planning and heavy industrialization became the cornerstone of India's development strategy. Following the adoption of planned economic development in 1951, India pursued an import substitution strategy aimed at establishing a diversified industrial base. The industrial policy resolution of 1956 assigned a dominant role to the public sector in basic and heavy industries, while private sector participants were regulated through a licensing mechanism. The achievement of this strategy was remarkable as within two decades, India developed industrial capabilities that many newly independent nations lacked. The country acquired the ability to produce steel, heavy machinery, chemicals and engineering goods on a significant scale. Balkrishnan (2007)

found that Indian economy experienced “resurgent growth” after independence and that the Nehruvian period 1950-64 represents a clear break from the stagnation of colonial economy. He estimated that GDP growth averaged around 4% per year and industrial growth production averaged around 7% to 8% per year significantly higher than growth recorded during late colony period and growth experience of many developed nations of that time. According to Bhattacharjee (2022), the policies during this period successfully created a broad manufacturing structure including steel, engineering, heavy machinery, chemicals and capital goods industries. However, evidences also indicate that excessive regulation generated inefficiencies and reduced competition. The *second* phase of industrial development is the time period from 1965-1980 and characterized by excessive controls and slow growth. A series of economic shocks exposed vulnerabilities in India’s development model. The country faced several droughts and reduced agricultural production and weakened demand for industrial goods. Along with this, the country fought wars with Pakistan in 1965 and 1971, diverting huge amount of resources towards defense expenditures. Some of the major International shocks such as global oil crises in 1973 and 1979 dramatically increased energy costs, raising production expenses across industries. Responding to these challenges, the government expanded economic controls and strict regulations to establish factories, expand production capacity, import new technology or introduce new products. This complex system came to be popularly known as the License Raj. Therefore, this phase is often regarded as the period of industrial deceleration and according to Ahluwalia (1985) “Industrial growth slowed to 3.7% per annum 1965-1976, compared with about 7.8% per annum during 1951-1965”.

At the same time, countries such as Japan, South Korea and China achieved a consistent and rapid economic growth through the policy of manufacturing led industrialization. On the other hand India, however, experienced comparatively slower industrial transformation. The critique pointed out that India’s post-independence industrial growth was severely throttled by state policies. While the post-independence industrial development strategy did manage to create a highly diverse capital goods foundation and robust scientific infrastructure, it fundamentally stifled the pace of transformation and broad based manufacturing employment growth. *Third* phase (1980-1991) of industrial development of India is the period of recovery and modernization. The 1980s era witnessed a gradual relaxation of industrial controls and greater emphasis on modernization, technological upgrades, easier access to imports of capital goods and policy

reforms. At the same time rising public investment and expenditure stimulated domestic demand. Industrial growth accelerated significantly during the 1980s and manufacturing sector became more dynamic. All these factors resulted into a remarkable industrial growth rate of approximately 8% per year between 1980 and 1990 (2022).

During 1991, a significant turning point occurred when India introduced comprehensive economic reform measures involving industrial delicensing, trade liberalization, foreign direct investment promotion and financial sector reforms. Many other areas previously reserved for the public sector were opened to private participation. Entry restrictions were removed and foreign companies entered the Indian market, bringing capital, technology and managerial expertise. These reforms fundamentally altered the ultimate determinants of industrial growth and transformed the industrial landscape by increasing competition, improving productivity, and integrating Indian industries with global markets. Although industrial growth rate was volatile during whole 1990s but the decade witnessed strong recovery with approximately 5% to 7% average growth per annum (mospi).

The growth of Industrial sector remained moderate between 2000 and 2003 but accelerated substantially after 2003. Growth rates exceeded 8% in several years and reached double digits around 2006-07 due to strong foreign and domestic investments, expansion of infrastructural projects, favorable global economic conditions. The period was briefly interrupted by the global financial crisis 2008 onwards, which reduced international demand and investment flows. Nevertheless, India recovered relatively quickly compared with many advanced economies. The Covid-19 pandemic caused the most severe disruption to India’s industrial sector since economic liberalization. According to the World Bank’s industry value-added data, India’s industrial sector contracted by approximately 5.5% in 2020, marking the first major industrial sector decline in decades (world bank-2025).

In developing economies, industrial growth is often influenced by many structural, institutional, technological and macroeconomic factors including capital formation and investment, exports and imports, market demand, energy availability, inflation, labor productivity and foreign direct investment (FDI). The growth of industrial sector has been shaped by a complex interaction of economic decision makings, institutional changes, infrastructure development, human capital formation, technological progress and global integration. Understanding how these variables affect industrial performance is important for policymakers seeking to design effective industrial and economic policies.

1.1. Statement of the Problem

Although India has achieved substantial industrial growth since independence, the sector's contribution to GDP and employment remains below the levels observed in many rapidly industrializing economies. Industrial growth has also been characterized by fluctuations and inter-industry disparities. Infrastructural constraints, financial limitations, incomplete global integration, inadequate technological capabilities and policy challenges continue to impede industrial expansion. Consequently, it becomes necessary to investigate the major determinants that significantly influence industrial sector performance in India. A systematic and long term time series analysis can provide empirical evidence regarding the relative importance of various economic factors affecting industrial growth.

1.2. Significance of the Study

This study is significant for several reasons:

1. Study is expected to contribute the understanding of industrial growth dynamics in India.
2. It identifies key determinants influencing industrial performance in the long run.
3. Empirical findings are expected to be helpful in designing strategies for policy formulation.

1.3. Objectives of the Study

This study aims to achieve the following objectives:

1. Identify the major determinants of India's industrial sector performance for the period of 1976-2024.
2. Estimate the impact of selected macroeconomic variables on industrial growth sector using ARDL regression analysis.
3. Estimate the short run and long run impact these variables on industrial growth.
4. Suggest policy measures for enhancing industrial development in India.

2. Literature Review

Industrial growth has long been regarded as a key driver of economic development, structural transformation, employment generation and technological progress. Classical economists such as Adam Smith, David Ricardo and later development economists such as W. Arthur Lewis emphasized the importance of industrialization in increasing productivity and accelerating economic growth. The industrial sector contributes to economic development by creating forward and backward linkages, promoting innovation, increasing exports and generating economies of scale.

Numerous studies have examined the factors influencing industrial growth in other developing economies and India. A large number of empirical findings demonstrate a positive relationship between investment and industrial growth. Public and private investment directly contributes to industrial output by increasing productive assets and indirectly through multiplier effects. A study by Bahal et al. (2018) found that public investment can stimulate private investment, thereby accelerating industrial development. Ahluwalia's (1991) study identified infrastructural constraints as a major factor behind industrial stagnation in India during the 1960s and 1970s. Poor infrastructure increased costs and limited industrial productivity.

Chenery and Syrquin (1975) demonstrated that countries which experienced rapid industrialization typically exhibit high rates of capital accumulation. Similarly, Rostow (1960) found that industrial take-off requires substantial increases in investment rates. Human capital theory suggests that education and skill formation significantly influence industrial growth. Becker (1964) argued that investment in education raises labor productivity and economic performance. Further, Lucas (1988) emphasized the role of human capital in generating technological progress and innovation. Industrial growth increasingly depends on skilled labor which is capable of adopting and utilizing advanced technologies.

In the globalized era, Foreign Direct Investment (FDI) has emerged as a major determinant of industrial growth. Theoretically, there are several channels through which FDI promotes industrial development. These include capital inflows, technology transfer, export market access, managerial expertise, and productivity spillovers. Borensztein, De Gregorio, and Lee (1998) demonstrated that FDI contributes more to growth than domestic investment because it embodies advanced technology and knowledge. Similarly, Blomstrom and Kokko (1998) found that foreign firms generate spillover effects that enhance domestic industrial productivity.

The relationship between trade openness and industrial sector growth has generated extensive debate. Traditional import substitution theories advocate protection of domestic industries through tariff and trade barriers. According to Prebisch (1950) and Singer (1950), developing countries require protection to nurture infant industries and reduce dependence on imported manufactured goods. Similarly, Joseph Stiglitz (2002) criticized rapid financial liberalization, by arguing that premature opening of capital markets can increase economic vulnerability, financial instability and likelihood of crises in developing economies. Likewise, Atiq et al. (2014) found mixed evidence regarding the impact of capital account openness

suggesting that while some developing countries experienced improved industrial and economic growth through increased capital inflows, others suffered from instability and economic crises. Prasad et al. (2005) argued that while financial globalization can facilitate access to foreign capital, technology transfer and financial market development, its growth benefits are not automatic and depend mostly on the quality of domestic institutions and macroeconomic policies. Conversely, export oriented growth theories emphasize international competition and market integration in his study, Balassa (1978) argued that trade openness promotes industrial growth by facilitating technology transfer, efficiency improvement and economies of scale. Empirical evidence largely supports the positive effects of trade liberalization. Edwards (1998) found that more open economies generally experience higher productivity growth. Sachs and Warner (1995) demonstrated that trade openness contributes significantly to industrial development.

Aiyedogbon and Anyanwu (2015) examined the impact of macroeconomic determinants on industrial productivity in Nigeria over the period 1981-2003. Utilizing Ordinary Least Squares (OLS) technique, they demonstrated the positive and significant effect of exchange rate on industrial productivity. The results further revealed that foreign direct investment (FDI), interest rates and real gross domestic product (GDP) positively influenced industrial productivity while consumer price index (CPI), broad money supply and credit to manufacturing sector exerted negative effects on industrial productivity.

Goldar and Sharma (2015) analyzed the determinants of industrial sector performance in India by using manufacturing data. They found positive and significant effect of foreign direct investment (FDI) on industrial productivity. Further they argued that infrastructure and technology adoption are strong supporting determinant and export oriented firms show higher productivity growth. Singh and Jyoti (2020) examined firm level determinants of performance in selected Indian manufacturing industries and found that productivity is strongly influenced by labor efficiency, capital investment, technological upgrading and R&D expenditure. The study further highlights that firms engaging in foreign collaboration and technology transfer tend to achieve higher turnover, while skill shortages and weak innovation capacity constrain industrial performance.

Sankaran et al. (2020) using time series data for 1990-2017 examined the impact of dynamic

Variables Description

Variable	Definition	
INDUS	Industry including construction value	Annual industry

macroeconomic variables on manufacturing output. Their finding through ARDL technique demonstrate that manufacturing output in India is primarily driven by capital formation, export performance and exchange rate dynamics, while inflation and external price shocks negatively affect industrial growth. Using data from more than 100 developing countries between 1970 and 2015, Haraguchi et. al. (2019) found that infrastructure development, demographic structure, human capital and export performance significantly influence industrialization. Their study concluded that successful industrialization requires a combination of favorable economic and institutional conditions. Ozyurt (2009) recommended the use of domestic credit to private as an indicator of financial sector development, arguing that greater access to credit enhances investment and industrial expansion. Inflation influences industrial development through its effect on investment decisions, production costs, profitability and macroeconomic stability. Literatures on inflation, including Paul et al. (1997), Sidrauski (1967), Fischer (1993), Barrow (1999) and Mamo (2012) found negative impact of inflation which adversely affects industrial development.

Research Methodology

This study employs a quantitative research design using annual time series data to investigate the determinants of industrial sector growth in India. This study focuses on measuring the statistical relationship between industrial growth and selected macroeconomic variables. Specifically, the study employed time series econometric modelling to estimate both short run and long run relationships among variables.

Nature and Sources of Data:

The study relies entirely on secondary data collected from internationally recognized database and institutional publications. Secondary data are preferable because they provide reliable, consistent and comprehensive macroeconomic information over long time periods. Data have been collected for the time period 1976 to 2024, from following sources:

World Bank Open Data

International Monetary Fund (IMF)

United Nations Industrial Development Organization (UNIDO)

The study uses annual observations covering the period from 1976 to 2024. The selected time period is sufficiently long to capture long-run industrial trends, structural changes and macroeconomic fluctuations affecting industrial performance.

	added percent of GDP	growth
GCF	Gross capital formation percent	Investment and productive

	of GDP	capacity
EXGS	Exports of goods and services percent of GDP	Trade Openness
FDIIN	Foreign direct investment, net inflows percent of GDP	Technology transfer and capital inflows
INF	Inflation, GDP deflator annual percent inflation	Macroeconomic stability
POPUL	Annual population growth rate	Labor and product market

1.2. Estimation Technique

Macroeconomic time-series data often exhibit trends and non-stationary behavior. Estimating regressions with non-stationary variables may lead to spurious regression results, where high R-square and significant t-statistics are obtained despite the absence of a meaningful economic relationship. Therefore, prior to time series regression analysis, the order of integration of each variable must be determined. This study employs the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests to examine the stationarity properties of the variables. The ADF test developed by David Dickey and Wayne Fuller (1979) has been used to determine whether a time series contains a unit root. To verify the robustness of the ADF results, study also utilized the PP test proposed by Peter Phillips and Pierre Perron (1988).

Variables Under Consideration:

To examine the determinants of economic growth, the study specifies an econometric model based on economic growth theory and previous empirical literature. The functional relationship is expressed as:

$$INDUS_t = f(GCF_t, EXGS_t, FDIIN_t, INF_t, POPUL_t)$$

Where, *Dependent Variable* – is industrial sector contribution (INDUS) which is measured using industry value added as percentage of GDP. Industry value added includes manufacturing, mining, construction, electricity and water supply.

Independent Variables

Gross capital formation percent of GDP (GCF) – Gross capital formation measures investment in physical assets such as machinery, equipment, factories and infrastructure. It is expected that GCF and INDUS is expected to have a positive association since higher capital formation increases production capacity and industrial productivity.

Exports of goods and services (EXGS) percent of GDP – Total exports of goods and services as percentage of GDP reflects trade openness and degree of integration of the economy into international markets. The expected sign of the coefficient of EXGS is positive as more demand from international market for industrial product would lead to increase in the domestic production and exports.

Foreign direct investment, net inflows (FDIIN) – It represents net foreign investment inflows into country as percent of GDP. FDI contributes to industrial growth positively through technology transfer, managerial skills and financial resources.

Inflation (INF) – Inflation is annual rate of price change based on Consumer Price Index (CPI). High inflation may reduce industrial performance by increase in production costs and creating economic uncertainty. Therefore a negative relationship is generally expected between industrial growth and inflation.

Population (POPUL) – Annual growth rate of population determines the availability of labor force and productive human resources in the economy. Along with this rate of growth of population may also determine the size of product market available domestically. The prior expectation with respect to population and industrial growth is positive.

1.3. Econometric Modelling

1. Basic time series Econometrics specification

Long Run Linear specification:

$$INDUS_t = \beta_0 + \beta_1 GCF_t + \beta_2 EXGS_t + \beta_3 FDIIN_t + \beta_4 INF_t + \beta_5 POPUL_t + \varepsilon_t$$

Where - β_0 is intercept and $\beta_1, \beta_2, \beta_3, \beta_4$ & β_5 are slope coefficients. ε_t is error term.

Log-Linear Specification

$$\ln INDUS_t = \beta_0 + \beta_1 \ln GCF_t + \beta_2 \ln EXGS_t + \beta_3 \ln FDIIN_t + \beta_4 \ln INF_t + \beta_5 \ln POPUL_t + \varepsilon_t$$

Here, $\ln$ is the natural log and $\beta_1, \beta_2, \beta_3, \beta_4$ & β_5 are partial elasticities w.r.t. to industrial growth.

2. Dynamic Specification

$$\ln INDUS_t = \alpha_0 + \alpha_1 \ln INDUS_{t-1} + \beta_1 X_t + \varepsilon_t$$

Where, $X_t = f(GCF_t, EXGS_t, FDIIN_t, INF_t, POPUL_t)$ and $\ln INDUS_{t-1}$ is natural log of industrial sector contribution one year before.

3. ARDL Model Specification

Most widely used specification used today in time series regression analysis is Autoregressive Distributed Lag (ARDL) model developed by Pesaran et al. (2001). It offers several advantages over conventional co-integration techniques. First, it allows the estimation of relationships among variables integrated of order I(0) and I(1). Second, it is efficient in small samples of time series. Third, the ARDL framework simultaneously estimates long run equilibrium relationship and short run dynamic adjustments through an Error Correction Model. Finally, the Bound testing procedure provides a robust method for examining co-integration among variables. Therefore, ARDL is considered the most appropriate econometric technique for investigating the determinants of industrial growth in India over time. The equation for ARDL specification is:

$$\ln INDUS_t = \beta_0 + \sum_{i=1}^p \beta_1 \ln INDUS_{t-i} + \sum_{j=0}^{q1} \beta_2 GCF_{t-j} + \sum_{j=0}^{q2} \beta_3 EXGS_{t-j} + \sum_{j=0}^{q3} \beta_4 FDIIN_{t-j} + \sum_{j=0}^{q4} \beta_5 INF_{t-j} + \sum_{j=0}^{q5} \beta_6 POPUL_{t-j} + \varepsilon_t \dots$$

Where - p, q1, q2, q3, q4, q5 are optimal lag length of dependent and independent variables respectively, based on Akaike Information Criterion (AIC) (Akaike 1979).

4. ARDL Bound Testing Specification

Following is the equation for ARDL Bound test approach which estimates the Unrestricted Error Correction Model (UECM):

$$\Delta \ln INDUS_t = \omega_0 + \sum_{i=1}^p \omega_1 \Delta \ln INDUS_{t-i} + \sum_{j=0}^{q1} \omega_2 \Delta \ln GCF_{t-j} + \sum_{j=0}^{q2} \omega_3 \Delta \ln EXGS_{t-j} + \sum_{j=0}^{q3} \omega_4 \Delta \ln FDIIN_{t-j} + \sum_{j=0}^{q4} \omega_5 \Delta \ln INF_{t-j} + \sum_{j=0}^{q5} \omega_6 \Delta \ln POPUL_{t-j} + YECT_{t-1} + \mu_t \dots$$

In the above equation Δ is the first difference operator and μ_t is white noise disturbance term.

ECT_{t-1} is generally referred as the Lagged Error Correction Term and contains:

$$ECT_{t-1} = \lambda_1 \ln INDUS_{t-1} + \lambda_2 \ln GCF_{t-1} + \lambda_3 \ln EXGS_{t-1} + \lambda_4 \ln FDIIN_{t-1} + \lambda_5 \ln INF_{t-1} + \lambda_6 \ln POPUL_{t-1} + \varepsilon_t$$

Where, Y is the coefficient of ECT which shows speed of adjustment from short -run disequilibrium back to long run equilibrium. The coefficient should be $-1 < Y < 0$ and statistically significant.

λ_i , i = 1,2,3,4,5,6 are coefficients used to show long term co-integration under the

Null Hypothesis

$$H_0: \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 = 0, \text{ and}$$

Alternative Hypothesis

$$H_1: \lambda_i \neq 0 \text{ for at least one coefficient}$$

To ensure the validity, reliability and robustness of the estimated ARDL model, several post-estimation diagnostic tests were conducted. These tests examined the presence of serial correlation, heteroscedasticity, normality of residuals and stability.

2. Results and Discussions

4.1. Descriptive Statistics

Table 1 presents the descriptive statistics of the variables under consideration. These measures provide insight into the distribution, variability and normality of data. The results indicate that industrial sector contribution to GDP recorded an average value of 27.2% during the study period, with a standard deviation of 1.80, suggesting moderate fluctuations in industrial performance. Gross capital formation exhibited a mean value of 29.5%, indicating a relatively high level of investment activity in the economy.

Table 1. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Industry	49	27.243	1.802	24.4	31.14
Capital Formation	49	29.507	5.855	19.42	41.95
Exports	49	13.977	6.879	5.2	25.43
FDI	48	.46	1.103	-1.502	4.514
Inflation	49	6.913	3.079	2.28	15.73
Population	48	1.769	.515	.79	2.41

Author's calculation

Exports of goods and services has witnessed high fluctuations with the standard deviations of 6.88 and registered a mean value of around 14%. FDI averaged a low value of 0.46, reflecting a lower contribution of foreign capital inflows to economic activities. Inflation averaged 6.9%, indicating a moderately inflationary environment and

population growth recorded an average value of 1.8% per annum, suggesting gradual reduction of population pressure. The comparison between the means values indicates that most variables are reasonably symmetric, although some differences suggest the presence of slight skewness in the data.

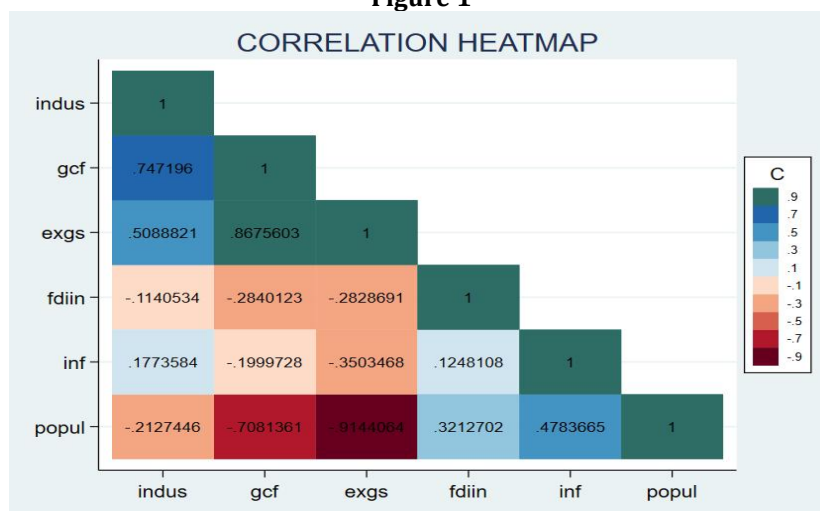
1.1. Correlation Analysis

Table 2. Pairwise Correlations

Variables	Industry	Capital Formation	Exports	FDI	Inflation	Population
Industry	1.000					
Capital Formation	0.710	1.000				
Exports	0.459	0.867	1.000			
FDI	-0.114	-0.284	-0.283	1.000		
Inflation	0.209	-0.211	-0.368	0.125	1.000	
Population	-0.213	-0.708	-0.914	0.321	0.478	1.000

Author's calculation

Figure 1



Author's calculation

Table 2 presents the pairwise correlation matrix and figure 1 showing heat-map matrix of industrial sector contribution to GDP and its various determinants. The results indicate that the INDUS is positively correlated with GCF, EXGS and INF with a correlation coefficient of 0.71, 0.45 and 0.20 respectively. This suggests that increase in investments and exports are associated with higher industrial growth. Conversely, FDI and POPUL exhibit negative correlation with the values of -0.11 and -0.21 which is opposed to the theoretical relationship. The coefficient values are well below the commonly accepted threshold of 0.80 and therefore, results suggest the absence of serious multicollinearity among the variables.

1.2. Stationarity Tests Results

Prior to estimating the ARDL model, stationarity properties of the variables were examined using the Augmented Dicky Fuller (ADF) and Phillips Perron (PP) unit root test. For both tests, the null hypotheses states that the time series contains a unit root and is therefore non-stationary, while the alternative hypothesis states that the series is stationary. The decision rule is to reject the null hypothesis when the p-value is less than critical value selected.

Table 3. Panel A: UNIT ROOT TEST TABLE (ADF) - Test - Levels

Variables	ADF	P.value	1% Critical	5% Critical	5% Critical	Decision
INDUS	-0.989	0.9456	-4.168	-3.508	-3.185	Non-Stationary
GCF	-2.487	0.3344	-4.168	-3.508	-3.185	Non-Stationary
EXGS	-1.715	0.7441	-4.168	-3.508	-3.185	Non-Stationary
FDIIN	-8.447	0.0000	-4.178	-3.512	-3.187	Stationary @1%
INF	-4.316	0.0030	-4.168	-3.508	-3.185	Stationary @1%
POPUL	-2.585	0.2869	-4.178	-3.512	-3.187	Non-Stationary

Panel B: UNIT ROOT TEST TABLE (ADF) Test – First Differences

	ADF	P.value	1% Critical	5% Critical	5% Critical	Decision
INDUS	-7.364	0.0000	-4.178	-3.512	-3.187	Stationary @1%
GCF	-9.808	0.0000	-4.178	-3.512	-3.187	Stationary @1%
EXGS	-6.855	0.0000	-4.178	-3.512	-3.187	Stationary @1%
FDIIN	-12.337	0.0000	-4.187	-3.516	-3.190	Stationary @1%
INF	-9.568	0.0000	-4.178	-3.512	-3.187	Stationary @1%
POPUL	-5.132	0.0001	-4.187	-3.516	-3.190	Stationary @1%

Panel A: UNIT ROOT TEST TABLE (PP)- Levels

	PP Z(t)	P.value	1% critical	5% critical value	10% critical value	Decision
INDUS	-0.989	0.9456	-4.168	-3.508	-3.185	NS
GCF	-2.487	0.3344	-4.168	-3.508	-3.185	NS
EXGS	-1.715	0.7441	-4.168	-3.508	-3.185	NS
FDIIN	-8.447	0.0000	-4.178	-3.512	-3.187	ST @1%
INF	-4.316	0.0030	-4.168	-3.508	-3.185	ST @1%
POPUL	-2.585	0.2869	-4.178	-3.512	-3.187	NS

Panel B: UNIT ROOT TEST TABLE (PP) – First Differences

	PP Z(t)	P.value	1% critical	5% critical value	10% critical value	Decision
INDUS	-7.364	0.0000	-4.178	-3.512	-3.187	ST @1%
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EXGS	-6.855	0.0000	-4.178	-3.512	-3.187	ST @1%
FDIIN	-12.337	0.0000	-4.187	-3.516	-3.190	ST @1%
INF	-9.568	0.0000	-4.178	-3.512	-3.187	ST @1%
POPUL	-5.132	0.0001	-4.187	-3.516	-3.190	ST @1%

Author's calculation

The results from ADF test indicate that FDIIN and INF were stationary at levels, implying integration of order zero, I(0). However, INDUS, GCF, EXGS and POPUL were found to be non-stationary at level but became stationary after first differencing, indicating integration of order one, I(1). Since the variables were integrated at a mixture of I(0) and I(1) and none of integrated of order two, I(2), the ARDL bound testing approach is considered appropriate for investigating the determinants of industrial sector growth. The Phillips-Perron (PP) unit root test has also been conducted to verify the robustness of the stationarity results obtained from ADF test. The findings of the PP test were similar and consistent with those of the ADF test which strengthens the reliability of stationarity analysis. Consequently, the ARDL model as employed to examine the determinants of industrial sector growth and the existence of a long run relationship among variables.

1.3. Auto-Regressive Distributed Lag (ARDL) Model Results

The optimum ARDL model selected using the Akaike Information Criterion (AIC) is ARDL (4,0,0,1,4) indicating 4 lags of the dependent variable and varying lag length for the explanatory variables. The selected model minimizes the information criterion and therefore provides the best balance between model fit and parsimony.

Table 4. Bound Co-integration Test

Test Statistics F = 5.679								
t = -4.693								
	10% Critical		5% Critical		1% Critical		P-Value	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
F	2.413	3.766	2.913	4.45	4.108	6.071	0.001	0.015
T	-2.475	-3.78	-2.838	-4.213	-3.577	-5.091	0.001	0.021

H0: no level relationship.

Decision rule. F > Upper bound – Co-integration exist

F < Lower bound – No co-integration

Between the bound - Inconclusive

Table 4 presents the result of ARDL bounds test for co-integration. The estimated F-statistics is 5.679 which exceed the upper bound critical value of 4.45 at 5% significance level. The absolute value of t estimated 4.69 are also greater than the upper bound critical value of 4.213 at 5% level of significance and thus again suggesting that null hypothesis of no level relationship is rejected. This provides evidence of long run relationship (co-integration) among industrial growth and its determinants despite short term fluctuations. Since a long run relationship has been established, it is appropriate to estimate the long run coefficients and associated Error Correction Model (ECM) to examine both the long run equilibrium relationship and short run dynamics.

Table 5. Long-Run Results

Variables	Long Run Coefficients	Std.Err.	t	Prob.	Sig.
INDUS. L1.	0.298	0.162	1.84	0.077	*
L2.	0.27	0.178	1.52	0.14	
L3.	0.154	0.186	0.83	0.414	
L4.	-0.251	0.144	-1.75	0.091	*
GCF	0.106	0.039	2.75	0.01	***
EXGS	0.137	0.064	2.12	0.042	**
FDIIN	-0.09	0.092	-0.97	0.339	
INF	0.117	0.051	2.28	0.03	**
L1.	-0.137	0.048	-2.83	0.008	***
POPUL	2.723	2.944	0.92	0.363	
L1.	-5.572	5.233	-1.06	0.296	
L2.	2.468	5.993	0.41	0.684	
L3.	-4.233	5.957	-0.71	0.483	
L4.	7.662	3.819	2.01	0.054	*
Constant	3.774	1.886	2	0.055	*
Model Statistics					
R-Squared	0.9346		F(14, 29)	29.59	
Adj R-Squared	0.9030		Prob > F	0.0000	***
Root MSE	0.5311				
Number of observation	44				

Author's calculation

Following the confirmation of a long run equilibrium relationship among the variables through the ARDL bounds test the long run coefficients were estimated to examine the persistent effects of the selected macroeconomic determinants on industrial sector growth. Table 5 presents the estimated long run coefficients, standard errors, t statistics and probability values. The positive coefficient of the first three lagged dependent variable INDUS suggests that higher industrial sector contribution to gross domestic product (GDP) in the previous period contributes positively to current industrial contribution, reflecting persistence in industrial production and investment. The first lag is statistically significant at 10% level implying that current industrial sector contribution influenced by its previous year performance but its impact declines when it goes beyond one year lag. Gross capital formation as percentage of GDP (GCF) has a positive and highly statistically significant long run effect on industrial sector contribution to GDP. Specifically, a one percentage-point increase in GCF is associated with 0.106 percentage-point increase in INDUS, holding other factors constant. This finding suggests that sustained increase in physical capital enhances industrial productive capacity, facilitates technological modernization and improves production efficiency.

Exports of goods and services as percentage of GDP (EXGS) exhibit a positive and statistically significant long run coefficient of 0.137 ($p < 0.01$). This indicates that, holding other factors constant, a one percentage point increase in EXGS leads to increase in the INDUS by 0.137 percentage point in the long run. This finding suggests that greater export activity stimulates industrial contribution to GDP by expanding access to international markets and encouraging firms to operate at larger scales. Consequently, exports serve as an important long term determinant of industrial sector. Foreign direct investment-net inflows (FDIIN) have a negative but statistically insignificant long run relationship with industrial sector contribution to GDP (INDUS). The result shows that a one percentage point increase in FDIIN is associated with a small decline in INDUS (-0.09) in the long run; however, this effect is statistically insignificant, indicating that the relationship is not robust. This result contrasts with endogenous growth theory but may reflect limited absorptive capacity or sectoral misallocation of foreign investment.

The ARDL result indicates that inflation has a dynamic effect on industrial sector. While current inflation positively and significantly (5% sig level) influences industrial growth, its lagged value exhibits a negative effect that is significant at 10% level. Specifically, it shows with one percentage point increase in current inflation leads industrial sector contribution to grow by 0.117 percentage points. This suggest that inflation may initially coincide with higher industrial activity, possibly due to demand expansion or rising output prices; however, the increase in inflation begin to adversely affect industrial performance with a time lag. The log of population (POPUL) shows both contemporaneous and lagged effects on industrial sector contribution to GDP (INDUS). The current coefficient is positive (2.72) but statistically insignificant, indicating that population does not have a reliable immediate impact on INDUS. In contrast, the four period lag of POPUL is positive and significant at 10% level with a coefficient of 7.66, implying that a 1 percentage increase in population four periods earlier increases current industrial sector performance by 7 percentage points. This suggest that the impact of population on INDUS materialize with a delay, reflecting the time required for individuals to enter the labor force, acquire skills and contribute to productive activities. Additionally, the population growth expands market size and stimulates industrial demand over time. Overall, the findings indicate that population is along run driver of industrial sector contribution rather than a short run determinant.

Table 6. Short-Run Results

Variables	Coef.	Std.Err.	t	Prob.	Sig
Panel A Error Correction Term ECT(-1)					
(-1)	-0.492	0.135	-3.64	0.001	***
Panel C - Short Run Coefficients					
Δ INDUS (-3)	0.269	0.144	1.87	0.087	*
Δ GCF	.0322	.0472	0.68	0.501	
Δ EXGS	-.0081	.0851	-0.10	0.925	
Δ FDIIN	-.087	.0920	-0.95	0.351	
Δ INF	.149	.055	2.71	0.012	**
Δ POPUL	.1011	2.975	-0.03	0.973	
Constant	3.34	2.004	1.66	0.108	
Model Statistics					
R-Squared	0.687				
Adj R-Squared	0.483				
Root MSE	0.5362				
Number of observation	44				

Author's calculation

The short run ARDL results presented in table 6, explains the immediate or temporary effects of the explanatory variables on industrial sector growth before the economy converges to its long run equilibrium. The interpretation focuses on the coefficients of the differenced variables and the error correction term (ECT). The error correction term (ECT) is negative and significant, confirming a stable long run relationship between industrial sector contribution to GDP (INDUS) and its determinants. The coefficient of 0.487 implies that approximately 49% of any short run disequilibrium in the INDUS is corrected within one period, showing a relatively fast adjustment toward long run equilibrium.

The positive and weekly significant (at 10% level) coefficient of the third lag of INDUS indicates that past changes in industrial sector performance continue to influence current growth after three periods. The result shows that with 1 percentage point increase in INDUS three periods ago leads to a 0.267 percentage point increase in current industrial sector contribution, suggesting delayed persistence in industrial sector dynamics. The positive coefficient of gross capital formation to GDP ratio (GCF=0.0364) suggests that although increased investment is associated with higher industrial sector contribution to GDP (INDUS), the relationship is not statistically significant in the short run. The result indicates that with 1 percentage point increase in the GCFT leads to 0.0364 percentage point increase in the INDUS. This implies that capital investments do not immediately stimulate industrial output, possibly because of implementation delays.

The coefficient of exports and imports of goods and services as percentage of GDP (EXGS) is -0.006, indicating that a 1 percentage point increase in EXGS is associated with a 0.006 percentage point decrease in INDUS in the short run, holding other factors constant. However, the coefficient is statistically insignificant, suggesting that there is insufficient evidence to conclude that EXGS have a meaningful short run effect on industrial sector growth during the study period. The coefficient of the first differenced FDI net inflows (FDIIN) is -0.079, implying that a 1 percentage point increase in FDIIN has resulted into a 0.079 percentage point decrease in the INDUS in the short run, holding other factors constant. However, the coefficient is statistically insignificant, meaning that there is insufficient evidence to reach upon any strong conclusion about the impact of FDIIN on INDUS in the short run during the period of study. This may be because the benefits of FDI often materialize over time through technology transfer, capital accumulation, productive investment and technology spillovers.

The estimated coefficient of inflation is 0.154, indicating that a 1 percentage point increase in inflation is associated with a 0.154 percentage point increase in industrial sector contribution (INDUS) in the short run, *ceteris paribus*. The coefficient is positive and statistically significant at the 5% level, suggesting that inflation exerts a significant positive influence on INDUS during the study period. The positive relationship may be attributed to increased aggregate demand and improved profitability, which can encourage firms to expand production in the short run. The positive but insignificant coefficient of 0.101 implies that population growth has no robust short run effect on industrial sector contribution (INDUS). The result shows that with 1 percentage point increase in annual population leads to 0.101 1 percentage point increase in INDUS, holding other things constant. This implies that population change does not have a clearly identifiable short run impact on industrial performance in the sample period. Consequently, the enhancing effects of such variables may be more evident in the long run rather than in the short run.

1.4. Post Estimation Diagnostic Tests

After estimating ARDL model, diagnostic tests are performed to verify that the model satisfies the assumptions of classical regression. A well specified ARDL model should have no serial correlation, no heteroscedasticity, normally distributed residuals, correct functional forms and stable parameters. The results in table 7, indicate that the estimated result is free from serial correlation, as the Breush-Godfrey LM test failed to reject the null hypothesis of no autocorrelation ($p > 0.05$). This indicates that residuals are independently distributed and the ARDL model does not suffer from autocorrelation. Consequently, the estimated coefficients are efficient and the associated standard errors are reliable. Breush-Pagan test yielded a Chi-square statistics of 0.13 with a p-value of 0.7197 and White test produced a Chi-square statistics of 0.44 with a p-value of 0.4290. Both tests of heteroscedasticity failed to reject the null hypothesis of homoscedastic error variances, since the p-value exceeds the 5% significance level. Therefore, the residuals exhibits constant variance, implying that heteroscedasticity is not a concern in the estimated ARDL regression model.

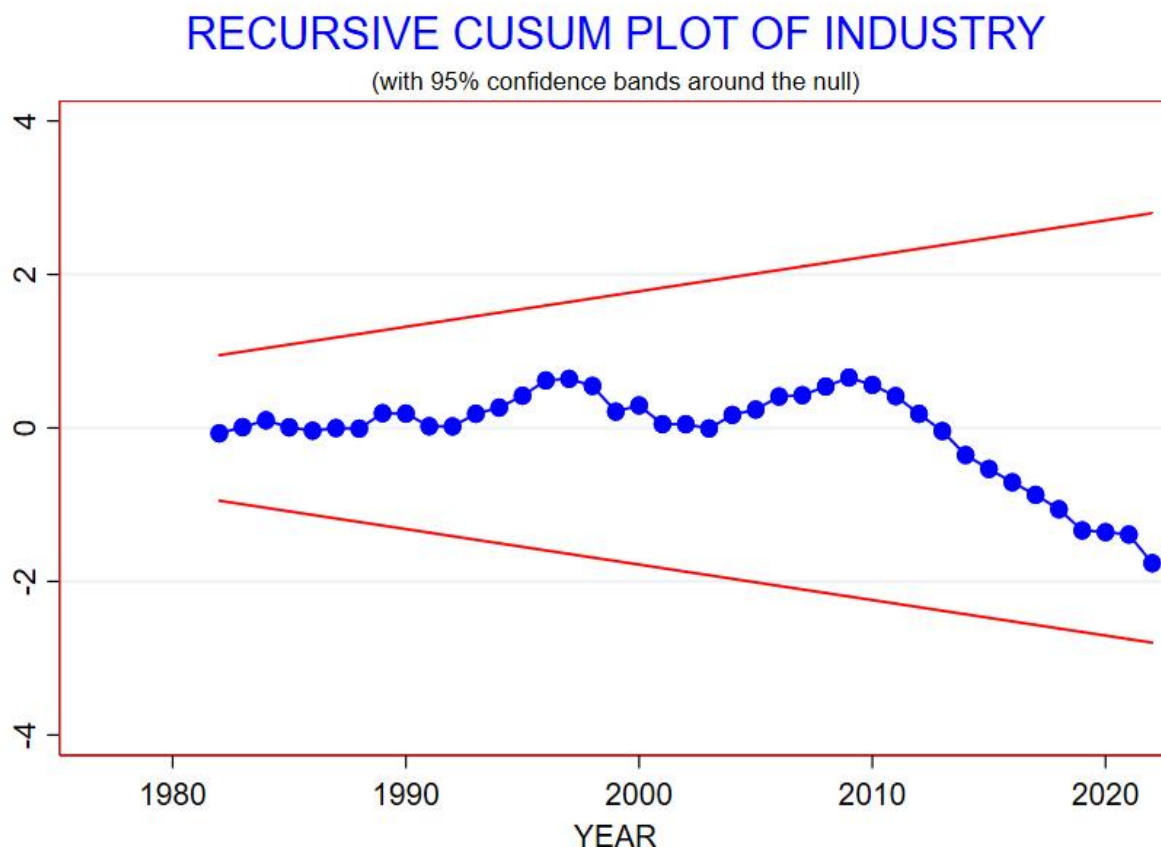
The Skewness/Kurtosis and Jarque-Bera (JB) test was conducted to assess whether the residuals of the estimated ARDL model are normally distributed. The joint SK test produced a Chi-square statistics of 0.11 with a p-value of 0.9447 and JB test has a Chi-square statistics of .2552 with a p-value of 8802. Since the p-value is greater than the 5% significance level, the null hypothesis of normality cannot be rejected. This indicates that residuals do not differ significantly from a normal distribution. The Ramsey Regression Specification Error Test (RESET) has been performed to evaluate whether the estimated regression model has omitted important explanatory variables or suffer from incorrect functional form. The derived F- statistics for the Ramsey RESET is 2.50, with a probability value of 0.0816. Since the p-value is greater than 0.05, the null hypothesis of 'model is correctly specified' cannot be rejected. Therefore, there is no evidence of functional form misspecification, suggesting that the selected ARDL model adequately captures the relationship between the dependent and explanatory variables.

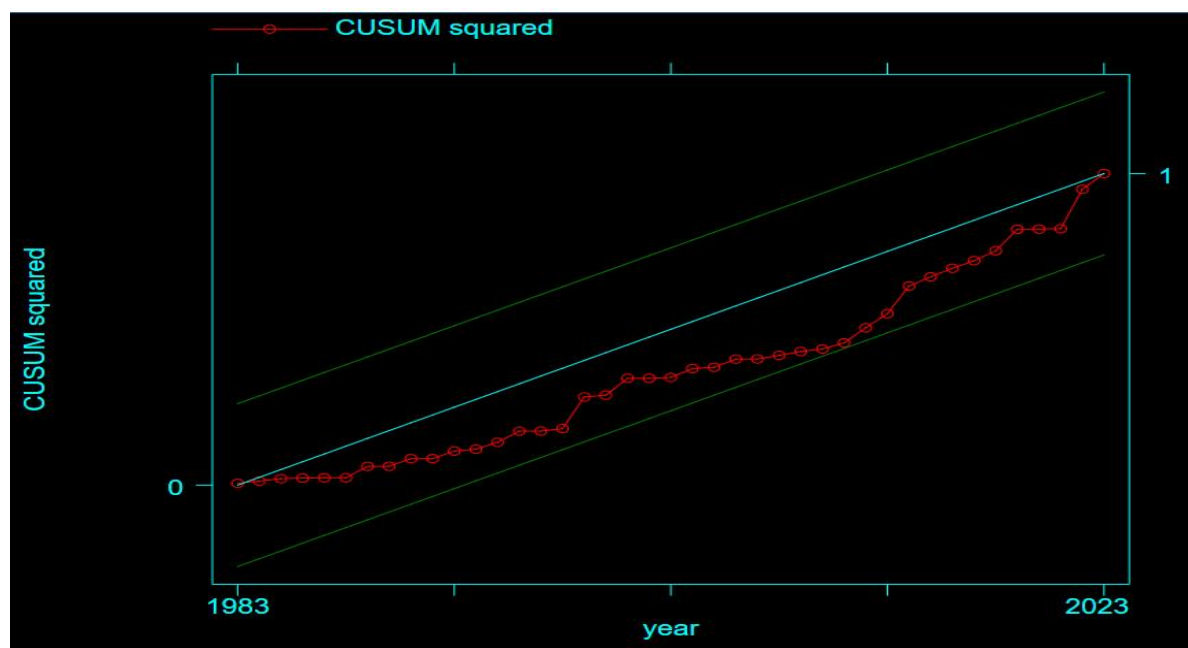
Table 7. Post Estimation Diagnostic Tests

Diagnostic Test	Test Statistics	p-value	Decision
Breusch-Godfrey LM	0.004	0.9483	No serial correlation
Breusch-Pagan/Cook-Weisberg	0.13	0.7197	No heteroscedasticity
White test for heteroscedasticity	44.00	0.4290	No heteroscedasticity
Skewness/Kurtosis (joint)	0.11	0.9447	Residuals normally distributed
Jarque-Bera (JB)	.2552	.8802	Residuals normally distributed
Ramsey RESET F(3,26)	2.50	0.0816	Model correctly specified

Model Stability Test - (CUSUM & CUSUMSQ)

The stability of estimated coefficients over time is essential for ensuring that the long run and short run relationships remain consistent throughout the sample period. The Cumulative Sum (CUSUM) test is one of the most important post estimation diagnostic tests in ARDL model to examine whether the estimated regression coefficients remain stable over time. The CUSUM plot has been shown in figure 2, which remained within the upper and lower critical bounds at the 5% significance level throughout the estimated time period. This result indicates that the estimated coefficients are structurally stable and no significant parameter instability occurred during the study period.

Figure 2.**Figure 3.**



The stability of the estimated ARDL model was assessed using the CUSUM of Squares (CUSUMSQ) test. As shown in figure 3, the CUSUMSQ plot remains within the upper and lower 5% critical bounds over the entire sample period. Since the cumulative sum of squared recursive residuals does not cross the critical boundaries, the null hypothesis of parameter stability cannot be rejected. This finding indicates that the estimated ARDL model is structurally stable and that there is no evidence of significant structural changes affecting the estimated coefficients during study period. Therefore, the estimated short-run and long-run relationships are considered reliable for statistical inference, forecasting and policy analysis.

2. Conclusions:

The study examined the macroeconomic determinants of industrial sector growth in India using the Autoregressive Distributed Lag (ARDL) approach with annual time series data for the period 1976 to 2024. The ARDL methodology was selected because it accommodates variables integrated of mixed order, $I(0)$ and $I(1)$ and enables the estimation of both long run and short run relationships. The empirical analysis provides strong evidence of stable long run equilibrium relationship between industrial sector contribution and its key determinants, confirming that macroeconomic and structural factors jointly influence the performance of India's industrial sector. The findings reveal that gross capital formation, foreign trade and inflation have positive and significant effects on industrial growth in the long run. The findings suggest that inflation may initially be positively related with higher industrial activity, possibly due to expansion in demand or rising output prices; however, the increase in inflation begin to affect industrial performance adversely with a time lag. The error correction model (ECM) confirms a significant speed of adjustment towards long run equilibrium, indicating that deviations from equilibrium are corrected quickly following short run economic shocks. Furthermore, diagnostic and stability tests demonstrate that the estimated ARDL model is statistically reliable, free from major econometric problems and stable over the study period. These findings enhance the credibility of the estimated relationship and support the robustness of the study conclusions.

The results carry important policy implications for India's industrial development strategy. Policymakers should prioritize investment in physical and digital infrastructure, facilitate greater domestic and capital investment and maintain a stable macroeconomic environment characterized by moderate inflation. Continued reforms to improve the business conditions, strengthen financial markets, promote innovation & research, develop skilled human capital and encourage technology adoption will further enhance industrial productivity and global competitiveness.

Despite its contribution, the study has certain limitations. The analysis is based on aggregate annual data and therefore does not capture variation across individual manufacturing industries or states. In addition to this many technological, financial, demographic and environmental factors could not be taken into account due to uniform data availability constraint. Future research may extend the analysis by using sector-specific or state level panel data. Advanced econometric techniques, including nonlinear ARDL, panel ARDL, threshold regression or structural vector autoregression may also provide deeper insight into the evolving dynamics of India's industrial sector. Overall, the study concludes that sustainable industrial growth in India depends on strengthening the mentioned determinants through consistent and evidence based policy measures.

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