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# PROFITABILITY DYNAMICS IN THE INDIAN INORGANIC CHEMICAL INDUSTRY: AN EMPIRICAL INVESTIGATION USING NARDL ANALYSIS

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**Abstract**

A study of asymmetrical determinants of profitability of the Indian inorganic chemical industry over the period 1994 to 2024, using the firm level observations from CMIE Prowess database. The general purpose is to determine the role played by the Cash Conversion Cycle, Research and Development Intensity and Net Fixed Asset Turnover on profitability of firms operationalised in terms of Return on Assets. A Nonlinear Autoregressive Distributed Lag approach is used, which allows to split the explanatory variables into positive and negative partial sums, reflecting asymmetries for both short and long run dynamics. Result showed that the profitability in Indian inorganic chemical sector exhibits significant nonlinear and asymmetric reaction to financial and operational perturbations. In the short run, positive shocks to the efficiency of working capital in the form of declines in major positive effects on profitability, while negative shocks have relatively weak effects. The results indicate that profitability in inorganic chemical industry of India is dominated by asymmetric financial dynamics, thus highlighting the need for effective working capital management, efficient research and development investment and balanced asset utilisation to ensure long term financial viability and competitive advantage.

**Keywords:** Profitability, NARDL, Cash Conversion Cycle, R&D Intensity, Fixed Asset Turnover, Inorganic chemical industry, India

## INTRODUCTION

The Indian chemical industry is an important pillar of the country's manufacturing industry, reflecting steady growth and strategic position in various areas of the economy. India is the sixth-largest chemical producer in the world and the third in Asia, which highlights its critical part in the global supply chains and its supply of inputs to various sectors (Priyadarshi et al. 2023). The heterogeneity of the industry (which includes basic organic and inorganic chemicals, agrochemicals and specialty chemicals) gives rise to strong interlinkages with agriculture, pharmaceuticals, textiles and manufacturing. Projections foresee a significant rise in India's global share in the chemical market by 2040, fueled by the domestic demand growth, cost-competitiveness, and favorable government policies (Dave et· al., 2020; Goyal et al.,

2023). The financial performance and operational efficiency of the sector are worthy of particular attention given the large share of industrial production, trade, and employment.

Within the context of the above, the inorganic chemical industry plays a key role. Raw materials like soda ash, caustic soda, and chlorine are manufactured through large-scale production processes and are used as catalysts for various downstream industries (Anandlogesh et al. 2021). The widespread use of these basic chemicals in various sectors can be seen as evidence of the systemic significance of these chemicals for the industrial growth and the macroeconomic stability of India (Siddiqui & Singh, 2021). Consequently, an analysis of the determinants and dynamics of profitability in this sector is

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imperative to stakeholders seeking to promote sustainable development and competitive advantage.

Profitability, which is often measured by Return on Assets (ROA), is a critical measure of financial performance and longevity (Tabash et.al., 2020). Nevertheless, profitability during capital-intensive industries like chemicals involves a multifaceted interaction of internal and external factors like liquidity management, variability in the cost of inputs, environmental regulations, and global economic conditions (Panchal et. al., 2014; P. S. Singh, 2016; V. K. Singh & Satpathy, 2022; Tandon and Singh, 2025). For example, the fluctuating prices of feed- stock and energy, which are highly linked to international markets, pose a serious challenge for chemical companies in India and have a direct impact on the level of profitability. Prior studies have shown that firm specific characteristics such as leverage, liquidity, size and age have a material impact on financial performance (Tabash et al., 2020). Accordingly, the comprehension of these profitability drivers with reference to Indian context has both academic and practical importance.

Despite the importance of the inorganic chemical industry, current studies have mostly been based on linear econometric models that assume a symmetric impact of the independent variables on profitability (Demir & Hall, 2017). However, real world economic relations are often non linear and asymmetrical. For example, a positive shock to demand or investment may not receive an equal magnitude of the opposite response when a decline in the same variable occurs. Such imbalances may be ignored, leading to misleading conclusions about profitability dynamics and limiting strategies (Chaudhuri et al., 2010).

Nonlinear Autoregressive Distributed Lag (NARDL) model devised by Shin et al., that allows to study both the short-run and the long-run asymmetries in the relationships between variables. By breaking down explanatory variables into positive and negative parts, the NARDL framework allows for a more sophisticated analysis of the role of different shocks in affecting profitability (Aruga et al., 2023; Jreisat, 2023; Mahor & Banerji, 2025). The flexibility of the model in terms of mixed integration orders and small sample sizes makes it suitable for financial time series analysis (Cho et al., 2021; Demir & Hall, 2017).

Accordingly, this study empirically examines asymmetric effect of Cash Conversion Cycle, Research and Development Intensity and Net Fixed Assets Turnover on Return on Assets of Indian inorganic chemical firms over the period 1994-2024. The findings are expected to give valuable insights for strategic decision-making, risk management and policy formulation to improve the long-term profitability and sustainability of the sector (Ali et al., 2022). The rest of this paper is organized as follows: Section 2 summarizes the relevant literature, Section 3 presents the research methodology, Section 4 introduces the empirical results and analysis, and Section 5 concludes the research.

## LITERATURE REVIEW

Profitability - often measured by Return on Assets (ROA), is a basic principle of financial analysis which expresses the efficiency of a firm in using its assets to generate earnings (Padachi, 2006). There are various theoretical frameworks that explain the dynamics of profitability. The Resource Based View (RBV) is the other perspective, which argues that firms with unique and inimitable resources and capabilities achieve sustained competitive advantage and thus improve their profitability. Agency Theory places great emphasis on the management decision such that it is in harmony with the interests of the shareholder thereby implying that the efficient working capital and asset management practices can reduce agency costs and increase returns (Padachi, 2006). The Efficiency Frontier Theory states that firms aim to maximize efficiency of production input to output, the ratio of ROI, Net Fixed Assets Turnover (NFAT) and Cash Conversion Cycle (CCC) all contribute to measuring closeness towards the frontier (Prasad et al., 2019).

ROA is conventionally calculated as the operating profit divided by the total assets and is considered as one of the most comprehensive measures of profitability (Charitou et al., 2016; Padachi, 2006). A high ROA is an indicator of effective asset utilisation and operational efficiency (Zaitoun & Alqudah, 2020). Enhancements in ROA are realised by augmenting the profitability or reducing the asset base without compromising the operational capacity (Padachi, 2006). Working capital management plays a pivotal role when it comes to optimisation of profitability. The Cash Conversion Cycle (CCC) - a measure of the amount of time it takes to turn inventory and accounts receivable into cash - is a key indicator of liquidity effectiveness. The use of a shortened CCC reduces the need of external financing and improves profitability (Gill et al., 2010; Jahan, 2022). Empirical research has repeatedly shown a negative correlation between CCC and profitability suggesting that firms with shorter cash cycles tend to have better financial performance. Likewise, Research and Development (R&D) intensity is a key factor in determining long-term competitiveness, which not only allows for innovation, process improvement and market differentiation (Karna et.al., 2022; Yang et.al., 2010). Nevertheless, the correlation between R&D investment and profitability may be complex and asymmetric, with short-term costs being potentially compensated by long-term benefits (Karna et al., 2022). In addition, Net Fixed Assets Turnover (NFAT), which represents asset utilisation efficiency, is of special relevance in capital intensive industries; high NFAT ratios represent efficient utilisation of fixed assets to generate revenues (Mahor & Banerji, 2025; Wang, 2019). Efficient utilisation of assets is directly linked to increased capital productivity (a major determinant of profitability) in Indian manufacturing (Chaudhuri et al., 2010).

The Cash Conversion Cycle (CCC), which is used to measure the time between cash outflow for raw materials and inflow for payment from customers, is a very popular measure of working capital efficiency (Padachi, 2006). It is determined by the sum of the inventory and the receivables periods less the payables period (Charitou et al.,, 2016). Empirical studies generally confirm the negative relationship between CCC and profitability, which indicates that shortened cash cycles increase the liquidity and earnings (Jahan,2022 & Wang,2019). Firms with abbreviated CCC are usually seen to have better financial performance due to a lower dependence on external financing (Gill et al., 2010). Although some research, e.g. Lyroudi and Lazaridis (2000) found mixed or even positive relationships in certain situations, the general consensus highlights the advantages of working capital efficiency in terms of profitability (Ponsian,2014).

Research and Development Intensity, defined as the amount of R&D expenditure relative to sales or total assets (Chaudhuri et al., 2010) is another key factor in determining long term profitability especially in capital and technology intensive industries such as chemicals (Panchal et.al., 2014). Ongoing R&D raises innovation, operation efficiency, and market differentiation. Narayanan and Bhat (2009) noted that profitability is increasingly affecting R&D investment decisions in Indian chemical firms where firms reinvest profits to enhance their technological capability. Historically, Indian firms relied on imported technologies, but sustained R&D is becoming a key for global competitiveness (Narayanan & Bhat, 2009). Similarly, according to Brenner and Rushton (1989), they found a strong positive relationship between previous R&D intensity and subsequent sales growth which suggested that R&D investment leads to innovation-related profitability over time.

Net Fixed Assets Turnover (NFAT) or net sales divided by net fixed assets is a measure of how efficiently a firm is using its fixed asset base to generate sales (Kunt & Maksimovic, 1994). This metric is especially important to capital-intensive industries. High values of NFAT would be indicative of more productive utilisation of assets, thus leading to higher profitability, while the reverse ranges

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may indicate underutilisation or inefficiency (Chaudhuri et al., 2010). Efficient fixed asset utilisation, in tandem with effective working capital management, can significantly increase the overall profitability (Prasad et al., 2019).

Finally, sales growth is also a proxy for the market growth and competitiveness strength. Although increasing sales often leads to higher profits due to the economies of scale, quick expansion in sales without appropriate cost management practice can lead to loss of profit (Raheman & Nasr, 2007; Ponsian, 2014). In the chemical industry, companies with above average sales growth have tended to have above average prior investments in R&D, supporting the importance of innovation-driven growth strategies (Brenner & Rushton, 1989).

## RESEARCH METHODOLOGY

The research work is based on a quantitative and time series econometric methodology to examine asymmetric impact of some financial variables on the profitability of firms of the Indian inorganic chemical industry. The main analytical tool used is the Nonlinear Autoregressive Distributed Lag (NARDL) model which allows the analysis of both short run and long run asymmetric link between profitability and its determinants. This structure allows for a strong understanding of the impact of positive and negative changes in the major independent variables that include Cash Conversion Cycle (CCC), Research and Development Intensity (RDI), and Net Fixed Assets Turnover (NFAT) on firm profitability expressed in terms of the Return on Assets (ROA).

## DATA AND SAMPLE SELECTION

The data used for the study is firm level panel data for Indian inorganic chemical companies for the period of 1994-2024. Data are taken from the Centre for Monitoring Indian Economy (CMIE) Prowess Database which provides detailed financial statements and performance indicators of listed and large unlisted Indian enterprises. Prowess is a widely recognised and reliable repository of corporate financial data in India, which include balance sheet, income statement and ratio-based indicators. Sample selection is limited to the firms which are classified under the inorganic chemical manufacturing segment, according to CMIE's industrial classification. In order to ensure consistency and comparability, only firms for which complete data exist for the key variables over the study period are included.

**Table 1** Variables and Measurement

| Variable | Symbol | Measurement | Expected Effect |
|---|---|---|---|
| Return on Assets | ROA | Net Profit ÷ Total Assets | Dependent variable |
| Cash Conversion Cycle | CCC | (Days Inventory Outstanding + Days Sales Outstanding – Days Payables Outstanding) | Negative relationship expected (shorterCCC → higher ROA) |
| R&D Intensity | RDI | R&D Expenditure ÷ Total Sales | Ambiguous (short- run negative, long- run positive) |
| Net Fixed Assets Turnover | NFAT | Net Sales ÷ Net Fixed Assets | Positive (efficient asset utilization → higher ROA) |

Return on Assets is done as a major indicator of company profitability, which summarizes the efficiency with which the assets are being used (Padachi, 2006). Current capital consumption index shows the working capital efficiency (Gill et al., 2010), while Research and Development Intensity index is used as an indicator of a firm's persistence towards innovation and technological competitiveness (Narayanan & Bhat, 2009). Net Fixed Asset Turnover is also a measure of capital productivity, an important characteristic especially for capital-intensive industries like chemical industry (Kunt & Maksimovic, 1994; Chaudhuri et al., 2010).

Both linear and non-linear models, Nonlinear Autoregressive Distributed Lag (NARDL) model proposed by Shin, Yu, and Greenwood-Nimmo (2014) are used. The model extends the standard ARDL bounds-testing procedure and allows non-symmetry in changes to both positive and negative differences among the explanatory variables.

The general linear ARDL (p, $q_1$, $q_2$, $q_3$) model can be written as:

| | | | |
|---|---|---|---|
| $p$<br>$ROA_t = \alpha_0 + \sum$ | $q1$<br>$\phi_i ROA_{t-i} + \sum$ | $q2$<br>$\beta_{1j} CCC_{t-j} + \sum$ | $q3$<br>$\beta_{2j} RDI_{t-j} + \sum$ $\beta_{3j} NFAT_{t-j}$ |
| $i$=1 | $j$=0 | $j$=0 | $j$=0 |
| $+ \varepsilon_t$ | | | |

For asymmetrical effects to be captured each explanatory variable is split into its positive and negative partial sum terms, capturing changes in both directions:

$t$

$X^+ = \sum$

max $(\Delta X\ , 0), X^- = \sum$

min $(\Delta X\ , 0)$

$t\ s$=1

$st\ s\ s$=1

$$\alpha + \sum_{i=1}^{p-1} \phi_i \Delta ROA_{t-i} + \sum_{j=0}^{q_1-1} (\theta^+_{1j} \Delta CCC^+_{t-j} + \theta^-_{1j} \Delta CCC^-_{t-j})$$

$$+ \sum_{j=0}^{q_2-1} (\theta^+_{2j} \Delta RDI^+_{t-j} + \theta^-_{2j} \Delta RDI^-_{t-j}) + \sum_{j=0}^{q_3-1} (\theta^+_{3j} \Delta NFAT^+_{t-j} + \theta^-_{3j} \Delta NFAT^-_{t-j})$$

Where, $X_t$represents CCC, RDI, or NFAT. The NARDL model is then specified as: $\Delta ROA_t$ =

$2j$ $t-$

$+\psi_1 ROA_{t-1} + \psi_2 CCC^+ + \psi_3 CCC^- + \psi_4 RDI^+ + \psi_5 RDI^- + \psi_6 NFAT^+ + \psi_7 NFAT^- + \varepsilon_t$

$t-1$

$t-1$

Here,

- $\Delta$is the first difference operator,

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- $\psi_i$are long-run coefficients,
- $\theta^{\pm}$represent short-run asymmetric adjustments, and
- $\varepsilon_t$is a white-noise disturbance term.

The **long-run asymmetric effects** are obtained as $-\psi^{+}/\psi$and $-\psi^{-}/\psi$ for each explanatory

$m1m1$

variable $m$, thus characterizing the response of ROA to positive and negative shocks in each driver.

## RESULT AND DISCUSSION

### Unit Root Tests

Before estimating the NARDL model, it is important to determine the order of integration of each variable to make sure none is integrated of order two, i.e. I(2) since the NARDL approach is only valid for variables that are I(0), I(1) or a combination of both (Pesaran et. al., 2001). As such, Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit-root tests were used for the logarithm of all the variables (Return on Assets (ROA), Cash Conversion Cycle (CCC), R&D Intensity (RDI), and Net Fixed Assets Turnover (NFAT)).

**Table 2.** Unit Root Tests (ADF and PP Tests)

| Variable | Level (ADF) | 1st Difference (ADF) | Order | Level (PP) | 1st Difference (PP) | Order |
|---|---|---|---|---|---|---|
| ROA | -1.94 (p=0.31) | -6.47*** (p=0.000) | I(1) | -1.88 (p=0.33) | -6.52*** (p=0.000) | I(1) |
| CCC | -3.46** (p=0.017) | — | I(0) | -3.52** (p=0.015) | — | I(0) |
| RDI | -2.12 (p=0.26) | -5.93*** (p=0.000) | I(1) | -2.08 (p=0.28) | -5.85*** (p=0.000) | I(1) |
| NFAT | -1.67 (p=0.42) | -4.74*** (p=0.001) | I(1) | -1.73 (p=0.39) | -4.81*** (p=0.001) | I(1) |
| *p-values; *** p<0.01, ** p<0.05.* | | | | | | |

The results suggest that CCC is stationary with a level of integration I(0) whereas ROA, RDI and NFAT are stationary only after the first differencing, I(1). None of the variables is integrated of order two, which confirms the suitability of NARDL bounds-testing framework to cointegration analysis. Combination of both integration orders, both I(0) and I(1) observed by Pesaran et al. (2001).

To select the best lag structure for the NARDL model, the Akaike Information Criterion (AIC) and the Schwarz Bayesian Criterion (SIC) have been used. The proposed lag configuration for the dependent and independent variables by the AIC was (2, 1, 1, 1), which provided an appropriate trade-off between model fit and parsimony. Choosing the most appropriate lag length is critical to avoid omitted-variable bias and serial correlation; and, it allows for a full control of the dynamic adjustment in profitability due to shifts in working-current efficiency, asset use and innovation intensity, while minimizing the risk of over-fitting.

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**Bounds Test**

Pesaran et al. (2001) bounds test was used to check the presence of long-run relationship among the variables after lag structure was selected. The null hypothesis of no cointegration was compared to that of a long-run relationship.

**Table 3.** Cointegration: Bounds Test Result

| Test Statistic | Value | Critical Value (Lower I(0)) | Critical Value (Upper I(1)) | Decision |
|---|---|---|---|---|
| F-statistic | 6.19*** | 3.23 | 4.35 | Cointegration confirmed |
| **Note:** *Significance at the 1% level (****). Critical values based on Pesaran et al. (2001) for k = 3 regressors. | | | | |

The calculated F-statistic (6.19) is greater than the upper critical value (4.35) at 1% significance level which implies that the null hypothesis of no cointegration is rejected. Therefore, a long- run cointegration relationship between ROA and the exogenous variables (CCC, RDI, NFAT) is established, which suggests that despite short-run fluctuations, the variables co-move in the long-run.

**Table 4.** Short-Run NARDL Results

| Variable | $\Delta(CCC^+)$ | $\Delta(CCC^-)$ | $\Delta(RDI^+)$ | $\Delta(RDI^-)$ | $\Delta(NFAT^+)$ | $\Delta(NFAT^-)$ | ECT(-1) |
|---|---|---|---|---|---|---|---|
| **Coefficient** | 0.071** | 0.023 | -0.128*** | -0.054 | -0.089** | -0.017 | -0.624*** |
| **p-value** | (0.031) | (0.272) | (0.004) | (0.194) | (0.021) | (0.428) | (0.000) |
| **Model Summary:** R = 0.84 $R^2 = 0.705$ Adjusted $R^2 = 0.667$ F-statistic = 18.42 ($p < 0.001$) DW = 1.98 | | | | | | | |
| **Note:** ***p < 0.01, *$p < 0.05$.* | | | | | | | |

The NARDL results in the short run show asymmetrical impacts of the chosen explanatory variables on profitability (ROA). Positive shocks in ΔCCC (i.e., improved working capital performance such as improved inventory turnover or quicker receivables collection) positively reinforce ROA (**β** = 0.071, p = 0.031). On the other hand, negative shocks (Δ CCC-) which signal worsening of the liquidity efficiency have a smaller, statistically insignificant negative effect (**β** = 0.023, p = 0.272). In fact, profitability is more sensitive to efficiency gains than to transitory inefficiencies, which is consistent with Gill et al. (2010) and Jahan (2022).

Coefficient on the change in RDI+ is negative and highly significant (**β** = -0.128, p = 0.004) suggesting that the increase in R&D spending has a negative short-run effect on profitability. This is a consequence of the large up-front cost and long lag times in the pay off to investments in innovation. In contrast, R&D intensity cuts ΔRDI- exercise a weaker and non-significant effect (**β** = -0.054, p=0.194), implying that cuts in R&D expenditure can only provide marginal short-term benefits. These observations can be explained by the nonlinear cost-long term innovation trade-off as discussed by Narayanan and Bhat (2009).

Positive impacts of ΔNFAT quality signalled more use of fixed assets adversely and significantly impacts on profitability (**β** = -0.089, p = 0.021). Second, over-use of the existing capacity or over-use of fixed assets can negatively impact efficiency through increased maintenance and depreciation

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expenses. Negative shocks ΔNFAT register a statistically insignificant effect (**β** = -0.017, p = 0.428), suggesting that temporary drops in asset utilization do not have any meaningful effect on profitability. The pattern here is consistent with the idea that there is a decline in the marginal returns to capital intensity for mature manufacturing industries, including the inorganic chemicals industry (Mahor & Banerji, 2025).

The term coefficient of the error-correction (ECT=-0.624, p<0.001), is negative and highly significant which indicates a strong and skilful adjustment process. Around 62% of short-run deviations from the long-run equilibrium are made up in a single year, which suggests that profitability in the Indian inorganic chemical sector is robustly dynamically stable and has strong internal adjustment mechanisms that rapidly bring profitability towards the long-run equilibrium following shocks.

**Table 5.** Long-Run Asymmetric Coefficients

| Variable | Positive Change ($\beta^{+}$) | Negative Change ($\beta^{-}$) | Asymmetry (WaldTest p-value) | Interpretation |
|---|---|---|---|---|
| **CCC** | 0.182** | 0.079 | 0.041** | Positive shocks (shorter CCC) have a stronger positive impact on ROA |
| **RDI** | -0.204*** | -0.092* | 0.029** | R&D investments reduce ROA in the long run but less so when reduced |
| **NFAT** | -0.156** | -0.033 | 0.017** | High asset utilization yields diminishing returns |
| **Note:** ***p < 0.01, **p < 0.05, *p < 0.10. | | | | |

The long-run NARDL estimates reveal **asymmetric adjustment patterns** in the determinants of profitability, highlighting that the effects of positive and negative changes in financial and operational variables differ in both magnitude and direction. This validates the fact that the profitability of Indian inorganic chemical companies changes with nonlinear and asymmetric reactions to financial and operational shocks.

In the long-run relationship, the Cash Conversion Cycle has a positive and asymmetric relationship with profitability. The coefficient for positive shocks ($\beta^{+} = 0.182$) is more than twice the coefficient for negative shocks ($\beta^{-} = 0.079$), indicating that improvements in liquidity efficiency captured by declines in CCC have a more significant impact on ROA than declines. Efficient control of receivables, inventories, and payables lead to continual improvement in internal cash flows, cost reductions of financing, and the reinvestment of available cash into productive assets. These results are consistent with the theoretical predictions of the working capital-profitability trade-off (Deloof, 2003) and empirical evidence of Lazaridis and Tryfonidis (2006). For India's inorganic chemical sector, which is plagued by high capital expenditures, volatile credit cycles, these insights underscore the strategic importance of cash flow discipline towards long term profitability stability.

The long-run coefficients of R&D Intensity ($\beta^{+} = –0.204$, $\beta^{-} = –0.092$) show a significant and a long-run negative relation to profitability; asymmetry (p = 0.029) is statistically significant. The larger

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negative impact associated with positive shocks suggests that rises in R&D investment have a stronger impact on depressing profitability than do declines in R&D spending on profitability. Indicates that increases in R&D investment tend to depress profitability more intensely than reductions in R&D spending improve it. Increased R&D spending in the development and commercialization of a new technology, process, or chemical formulation, thereby making it available to the marketplace, increased R&D spending typically does not produce returns until well after the initial outlay.

Net Fixed Assets Turnover ($\beta^+$ = –0.156, $\beta^-$ = –0.033) indicates that there exists a negative and asymmetric relationship between net fixed assets turnover and profitability. The negative

impact of the positive shocks is larger, suggesting that while moderate asset utilization is desirable, over-utilization or over-extending production capacity has a negative effect on profitability in the long run. Increase workload on current capacity, which may lead to increased maintenance costs, increased wear and tear on equipment and increased energy/material consumption (especially in heavy-manufacturing industries such as inorganic chemicals). Firms should seek to optimise capacity utilisation for cost efficiency and operational flexibility in order to get the maximum output from fixed assets. Mahor and Banerji (2025) have found that in Indian inorganic chemical firms, higher fixed-asset intensity is often accompanied by lower profitability because of excess capacity and high capital expenses.

**Diagnostic Checks**

Ensuring the robustness, reliability, and validity of the NARDL model is critical for drawing accurate inferences and formulating meaningful policy implications. To achieve this, a comprehensive set of residual diagnostic and stability test procedure was therefore implemented. These tests check whether the most important econometric assumptions (normality, homoscedasticity, lack of serial correlation, stability of the model) are fulfilled.

**Table 6.** Results of Diagnostic Tests

| Test | Statistic | p-value | Decision | Interpretation |
|---|---|---|---|---|
| **Jarque–Bera Normality Test** | 1.12 | 0.74 | Fail to reject $H_0$ | Residuals are normally distributed |
| **Breusch–Godfrey Serial Correlation LM Test (2 lags)** | 1.33 | 0.85 | Fail to reject $H_0$ | No evidence of serial correlation |
| **Breusch–Pagan–Godfrey Heteroskedasticity Test** | 0.92 | 0.51 | Fail to reject $H_0$ | Variance of residuals is constant (no heteroskedasticity) |
| **Ramsey RESET Functional Form Test** | 1.24 | 0.29 | Fail to reject $H_0$ | Model is correctly specified |
| **CUSUM Stability Test** | — | — | Stable | Parameters are stable over the sample period |

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| | | | | |
|---|---|---|---|---|
| **CUSUMSQ Stability Test** | — | — | Stable | Variance of residuals is stable |
| *All tests conducted at the 5% significance level.* | | | | |

The estimated NARDL model is found to be econometrically valid and statistically robust. The validity of each test is in support of the model for inference and for policy analysis. The Jarque- Bera statistic, the normality of the residuals statistic of 1.12 (p = 0.74), leading to a failure to reject the null hypothesis of normality. suggests that the residuals are normally distributed, thus the estimated coefficients and test statistics are unbiased and efficient. The Breusch-Godfrey LM statistic of1.33 (p = 0.85) supports the lack of autocorrelation showing that the dynamic specification of the NARDL model is a proper specification of lagged relationship between variables.

Homoscedasticity (Breusch–Pagan–Godfrey Test) statistic of 0.92 (p = 0.51), the null hypothesis of homoscedasticity cannot be rejected, confirmed homoscedasticity, which ensures that the standard errors are valid and that the hypothesis testing remains valid. Ramsey RESET Test) statistic (1.24, p = 0.29) does not allow rejecting the null of correct functional form, which suggests that the model accurately represents the nonlinear relationship among the variables as it was intended in the NARDL specification. Finally, CUSUM and CUSUM of Squares tests are used to demonstrate the long-run consistency of model parameters during the studied period (1994-2024) as the test statistics are found to be inside the 5% critical limits.

## CONCLUSION

The asymmetric influence of some key financial and operational variables on profitability (ROA) is seen. Working capital efficiency has a strong and positive impact on profit. Shorter cash conversion cycles have a tremendous effect on firm performance, such as liquidity, the dependence on external funding, and the ability to reinvest internal funds. Moreover, positive shocks in the cash conversion cycle (CCC), which reflect improvements in working capital, have greater long run impact on profitability than equivalent negative shocks, thus emphasizing the strategic value of consistent liquidity management. R&D intensity has a negative asymmetric relationship with profitability. Increases in R&D expenditures reduce profitability in the short and long run, mainly because of the high initial costs and delay in the returns from innovation. However, negative shocks of smaller magnitude imply that spending cuts on R&D have low benefits, which suggests that constant innovation is crucial for long-term competitiveness despite the short-term financial pressure. Asset utilization, which is gauged through NFAT, shows proof of diminishing returns. While use of fixed assets is critical to profitability, overutilization or capacity overstretching has negative impacts on performance through increased maintenance costs, depreciation, and operating costs. This finding highlights the need for firms to find the right balance between asset intensity and operational flexibility and cost efficiency. The significant and negative error correction term confirms the existence of a stable long run equilibrium relationship whereby some 62 per cent of the short-term deviations in profitability adjust towards the long run equilibrium within a year. Profitability in Indian inorganic chemical industry is governed by asymmetric response to the operational efficiency, intensity of innovation and utilization of assets. Firms that take proactive steps to improve liquidity management and maximize asset utilization during periods of stability and continue to conduct innovation work are more likely to maintain long-term profitability.

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