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Nonlinear Effects of R&D Intensity on Short-Run Profitability: Evidence from Firm-Level Panel Data

Dr. Shilpi Tyagi,
Department of Humanities & Social Sciences, Thapar Institute of Engineering & Technology, Patiala, India, E-mail id: shilpi.tyagi@thapar.edu

Abstract
Using a firm-level panel dataset, this study examines the short-term relationship between innovation investment and firm performance in the pharmaceutical industry. The study investigates whether R&D intensity has a linear or nonlinear impact on returns on capital employed (ROCE), drawing on the literature on the innovation–profitability trade-off. The analysis accounts for time-specific shocks and unobserved firm heterogeneity using a fixed-effects model with firm-clustered standard errors and lagged R&D intensity. The findings show that R&D intensity and profitability have a statistically significant nonlinear (convex) relationship. Higher levels of innovation investment mitigate the marginally negative effect, indicating the presence of learning effects and scale economies, even though initial increases in R&D intensity lower short-term financial performance. The industry's capital intensity pressures are indicated by the negative relationship between firm size and ROCE, with lifecycle effects playing a supporting role. The results point to the dynamic adjustment process that underlies innovation investment and imply that long-term R&D tactics could lessen immediate financial strains. Overall, the study adds to the body of literature by showing that nonlinear adjustment, as opposed to a straightforward linear trade-off, characterises the innovation–performance nexus.

Keywords: R&D Intensity, Innovation–Profitability Trade-off, Nonlinear Effects, Fixed-Effects Model, Pharmaceutical Industry

1. Introduction
Research and development (R&D) investment is an essential aspect of pharmaceutical companies' strategies; it is unclear how this will affect their short-term profitability. High upfront costs and uncertain commercialisation timelines may create concurrent financial pressures, even though innovation expenditure is anticipated to improve long-term performance (Johansson and Lööf, 2008; Lee, 2018; Rađenović et al., 2023). The Indian pharmaceutical industry has emerged as one of the most dynamic segments of the country's manufacturing sector, playing a significant role in global healthcare supply chains. With the help of a sizable pool of scientific talent, cost-effective manufacturing, and strong process innovation capabilities, India is widely acknowledged as a major producer of generic medications (Tyagi and Nauriyal, 2018; Sharma et al., 2023). Leading companies have been moving away from pure generics over the last 20 years and toward complex formulations, speciality medications, and research-driven initiatives. Export markets, especially regulated areas like the US and Europe, have grown to be significant revenue generators, which motivates businesses to make investments in technological advancement and quality compliance. However, pricing laws, growing R&D expenses, and competitive pressures still influence how profitable a company is. The Indian pharmaceutical industry is a crucial setting for researching the connection between financial strategy, innovation investment, and firm performance in emerging economies because of its dynamic structure.

This paper examines the relationship between R&D intensity and profitability using panel data for leading Indian pharmaceutical companies over 2015–2024. A firm fixed-effects framework is employed to control for unobserved heterogeneity, while lagged R&D measures capture delayed innovation returns. The baseline specification models return on assets as a function of contemporaneous and lagged R&D intensity, controlling for export orientation, leverage, firm size, liquidity, and asset tangibility, with standard errors clustered at the firm level.

There is a dearth of empirical studies regarding this short-term trade-off, especially for pharmaceutical companies operating in emerging markets where financial and regulatory constraints coexist with innovation expansion. First, the study provides concise panel evidence on the short-run profitability trade-off associated with innovation investment in an innovation-intensive emerging economy. Second, by explicitly distinguishing contemporaneous and lagged effects within a parsimonious econometric design, the paper offers clear evidence on the timing of R&D returns.

2. Data, conceptual framework, and Methodology

2.1. Data

An unbalanced panel of top Indian pharmaceutical companies listed on major stock exchanges between 2010 and 2024 is used in the empirical analysis. The CMIE ProwessIQ database, which offers standardised accounting data for publicly traded Indian companies, is the source of firm-level financial data. Businesses in the biotechnology and pharmaceutical sectors are included in the sample; they were chosen based on reliable data on R&D spending and profitability.

2.2. Conceptual framework

In empirical studies of corporate performance and industrial organization, firm profitability is modelled as a function of innovation investment and a set of firm-level controls (Roberts, 2001; Blažková, & Dvouletý, 2018; Bonanno et al., 2023). R&D intensity (RDI), which is calculated by scaling research and development expenditure by net sales, is the primary explanatory variable. The short-term financial burden of innovation investment is reflected in the RDI, which also measures the relative commitment of businesses to innovation activities. Table 1 portrays conceptual framework.

Few control variables are included to take into consideration the diversity of firm characteristics. Firm age (Age) accounts for cumulative organisational experience and lifecycle effects. A dummy variable called group affiliation (Groupdum) is used to identify companies that are part of larger business groups that might profit from shared resources and internal capital markets.

Table 1: Conceptual Framework

Variable	Definition	Measurement
Dependent Variable		
ROCE	Firm profitability	Calculated as earnings before interest and taxes (EBIT) divided by capital employed
Independent variable		
RDI	R&D intensity	R&D expenditure divided by net sales
Age	Firm age	Number of years since incorporation

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Groupdum	Business group affiliation	Dummy = 1 if firm belongs to a business group, 0 otherwise
XI	Export intensity	Export revenue divided by total sales
lnTA	Firm size	Natural logarithm of total assets

Export intensity (XI), which is calculated as the ratio of export revenues to total sales, is included to account for competitive exposure and outward market orientation. To account for scale effects and financial capacity, the natural logarithm of total assets (lnTA) is used as a proxy for firm size.

2.3. Methodology

The study looks at the nonlinear relationship between innovation investment and short-term profitability using a panel data model at the firm level. A fixed-effects specification with year dummies is estimated to account for common time shocks and unobserved firm heterogeneity. To reduce simultaneity bias, R&D intensity is introduced in lagged form, and possible nonlinear adjustment effects are captured by a quadratic term. Heteroskedasticity and serial correlation are addressed by clustering standard errors at the firm level. This is the estimating equation:

$$ROCE_{it}=\beta_0+\beta_1 RDI_{it-1}+\beta_2 RDI^2_{it-1}+\beta_3 Age_{it}+\beta_4 Groupdum_{it}+\beta_5 XI_{it}+\beta_6 lnTA_{it}+\mu_i+\lambda_t+\varepsilon_{it}$$

To lessen the impact of extreme observations, all continuous variables are winsorized when required. By adjusting for structural firm characteristics pertinent to the Indian pharmaceutical industry, these variables collectively enable us to isolate the relationship between R&D investment and short-term profitability.

3. Results and discussions

A fixed-effects model is employed and study findings indicate statistically significant nonlinear association between lagged R&D intensity and profitability. Results are shown in table 2. The relationship is convex, with a turning point at RDI ≈ 12.08, implying that moderate increases in RDI are most costly in the short run, while marginal effects improve at higher intensities. A Hausman test was conducted comparing fixed-effects and random-effects estimators. The results indicate the violation of the key random-effects assumption of orthogonality between individual effects and explanatory variables. Consequently, the fixed-effects specification is preferred.

Fixed-Effects Estimates of the Nonlinear Relationship Between R&D Intensity and ROCE			
Variables	**Coefficient**	**Standard error**	**P values**
RDI L1.	-1.071	0.44111	0.015
L1_RDI_sq	0.052	0.02468	0.034
Age	0.060	0.05866	0.304
Groupdum	0.538	1.45001	0.711
XI	0.000	0.00312	0.974
lnTA	-1.147	0.83258	0.168

Year effects			
2017	-0.884	1.33702	0.508
2018	-2.342	1.36011	0.085
2019	-0.818	1.36357	0.548
2020	1.163	1.37691	0.398
2021	3.146	1.39842	0.029
2022	1.255	1.42638	0.242
2023	-1.662	1.45416	0.012
2024	Omitted		
Wald chi^2 (14)	38.96	$p>chi^2$	0.0004
Number of observations	450	Number of groups	50
Source: Author's own estimations			

Interpreting RDI in percentage terms, ROCE is minimised at roughly 12% R&D intensity: below this threshold, marginal increases in RDI are associated with lower short-run ROCE; above it, incremental RDI is predicted to raise ROCE. Economically, this convexity can be interpreted as consistent with adjustment costs at low-to-moderate R&D effort which means spending does not immediately translate into revenues, followed by improved effectiveness once firms sustain R&D at commercially meaningful scale (Rađenović et al., 2023).

Turning to controls, firm size is economically meaningful: lnTA is negative and significant indicating that (within firms) expansions in the asset base are associated with lower short-run ROCE. Firm age is positive but not conventionally significant, suggesting lifecycle advantages that are imprecisely estimated under firm clustering. Year effects capture salient shocks: ROCE is higher in 2020 and lower in 2023 relative to the omitted base year, consistent with a temporary boom followed by a correction.

Managerially, the estimates caution against under-scaled R&D: modest increases at low intensity appear costly, whereas sustaining R&D near/above ~12% intensity may mitigate short-run profitability drag and improve marginal returns. Policy-wise, stable R&D incentives and predictable financing conditions can lower transition costs and help firms sustain R&D at scale. A limitation is that the turning point is sample-specific and residual endogeneity may remain.

At low to moderate levels of R&D intensity, firms face substantial adjustment costs—higher current expenses for pipeline development, clinical and regulatory compliance, and project screening—without immediate revenue realization, which compresses ROCE (Hazarika, 2021). At higher R&D intensity, however, firms appear to benefit from learning-by-doing and scale economies in innovation: accumulated know-how improves project selection and execution, absorptive capacity strengthens, and commercialization capabilities deepen.

4. Conclusions, policy recommendations, and directions for future research

This study uses a nonlinear panel data framework to investigate the short-term relationship between innovation investment and firm performance in the pharmaceutical industry. The empirical results show a convex relationship between lagged R&D intensity and profitability, suggesting that while innovation spending initially drives down returns on capital employed,

the marginal financial burden lessens as businesses continue to invest more in R&D. This pattern emphasises the existence of adjustment costs at lower levels of innovation, such as pipeline development, capability building, and regulatory compliance, which are followed by learning effects and scale economies that stabilise financial performance.

The findings also imply that lifecycle factors have a secondary but beneficial impact on short-term profitability, while firm size has a negative correlation, reflecting the capital-intensive nature of pharmaceutical innovation. Policymakers should concentrate on lowering the transition costs that businesses with moderate levels of innovation intensity must deal with, especially by streamlining regulatory processes, establishing clear approval schedules, and facilitating easier access to funding for clinical development. Businesses may be able to overcome the expensive initial phases of R&D investment and achieve efficiency-enhancing operational scales with the aid of targeted tax incentives or R&D subsidies intended to support ongoing innovation initiatives. Furthermore, improving cooperation between industry and research institutions may hasten the spread of knowledge and increase absorptive capacity, which would lessen the profitability drag connected to early innovation investments. From a policy standpoint, the results highlight the value of long-term, stable innovation ecosystems as opposed to temporary incentives that promote irregular R&D expenditures.

Under-scaled R&D strategies may be financially inefficient, according to the nonlinear relationship. While persistent and carefully planned R&D efforts can increase long-term resilience, businesses that devote only a small amount of resources to innovation may incur significant costs without seeing productivity gains. The findings collectively show that innovation investment in the pharmaceutical industry should be seen as a dynamic process that involves short-term financial trade-offs but may stabilise at higher R&D intensity levels. To better understand the relationship between innovation and profitability, future studies could expand this framework by investigating dynamic adjustment mechanisms or alternative performance metrics.

By offering firm-level proof of a nonlinear relationship between R&D intensity and short-term profitability within the pharmaceutical industry, this study adds to the body of research on innovation and performance. The results show a convex adjustment process, where initial innovation investment lowers financial performance but stabilises as firms achieve higher R&D intensity, in contrast to previous studies that assume a linear trade-off. By using lagged nonlinear specifications in a fixed-effects framework with clustered standard errors, the paper's methodology improves empirical evidence and makes it possible to identify within-firm dynamics with greater credibility. The study provides fresh perspectives on how consistent R&D investment influences financial resilience in innovation-driven industries by emphasising the role of scale and learning effects.

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