Journal of Open Innovation: Technology, Market, and Complexity 10 (2024) 100263

Contents lists available at ScienceDirect

Journal of Open Innovation: Technology, Market, and Complexity

journal homepage: www.sciencedirect.com/journal/journal-of-open-innovation-technology-market-and-complexity

Research and development intensity, inventory leanness, and firm performance

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ARTICLE INFO

Keywords:
R&D
Innovation
Lean strategy
Cost savings
Efficiency
Financial performance
Market performance

ABSTRACT

This study investigates whether a firm's research and development (R&D) intensity influences its choice of an inventory leanness strategy and how R&D intensity and inventory leanness collectively impact its performance. This study documents two findings in a dataset comprising 43,634 observations within the U.S. manufacturing sector from 1992 to 2019. Firstly, higher R&D intensity is associated with an increased likelihood of implementing an inventory leanness strategy. Secondly, adopting such a strategy helps firms mitigate the adverse effects of R&D spending on financial performance and generate additional market value. The results imply that managers in firms with high R&D spending strategically adopt inventory leanness to navigate uncertainties associated with realizing returns from their innovation activities.

1. Introduction

A firm's engagement in research and development (R&D) activities is often critical to long-term success. This is because they result in outcomes, such as patents and new products/services, which lead to high productivity (Aw and Song, 2013), positive sales growth (García-Manjón and Romero-Merino, 2012), and high market value (Ahmed and Falk, 2006; Chan et al., 1990; Chauvin and Hirschey, 1993). However, the R&D activities are also associated with a risk of failure. For instance, in 2006, Pfizer's project to develop a new drug was abandoned in the last phase of clinical trials when it had already invested around US$800 million (Herper, 2006). The announcement of abandoning that project resulted in an 11% reduction in Pfizer's stock price and a loss of US$21 billion market share (Berenson and Pollack, 2006). In a study of 211 R&D projects in 21 firms, Baker et al. (1986) note that the managers believe that only half of these projects will be technically and commercially successful. Even if the R&D projects are successful, they do not always guarantee financial returns (Zhang, 2015). As such, firms that spend more on R&D are expected to position alternatives to sustain profitability if financial returns from R&D are impractical.

This study proposes that inventory leanness is an alternative for high R&D-intensive firms that creates a backup if R&D generates less than expected returns. Inventory leanness refers to holding fewer inventories to save costs in the form of storage, insurance, and obsolescence risks, for instance. Prior research confirms this cost-saving effect by showing a positive impact of inventory leanness on firm performance (e.g., Elking et al., 2017; Roh and Lee, 2013). As such, inventory leanness may create a loop for high R&D-intensive firms to fill potential losses from R&D projects. Against this background, we examine whether a firm's R&D intensity guides its choice of adopting an inventory leanness strategy and, if so, explore the joint impact of R&D spending and inventory leanness on firm performance.

We measure inventory leanness based on the methodology in Eroglu and Hofer (2011). Specifically, we regress the firm's inventory on sales revenue, and the residual of this regression represents inventory leanness or non-leanness. We multiply this residual by -1 so that a positive (negative) residual indicates inventory leanness (non-leanness). The R&D intensity is defined as the firm's research and development spending scaled by total assets. The firm's financial performance is proxied by return on assets (net profit/total assets) and market performance by Tobin's Q (market value of equity plus total assets minus common shareholders' equity minus deferred tax, scaled by total assets).

Based on an examination of firms within the manufacturing industries in the U.S. from 1992 to 2019, this study finds a positive association between the firm's degree of R&D intensity and an indicator variable for inventory leanness. This implies that firms with high R&D spending are more inclined than other firms to adopt a lean strategy for their inventories. Specifically, firms with R&D intensity at the 75th

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https://doi.org/10.1016/j.joitmc.2024.100263
Received 1 December 2023; Received in revised form 24 March 2024; Accepted 28 March 2024
Available online 30 March 2024

percentile are found to be 15% more likely than those at the 25th percentile to follow a lean inventory strategy. Further analyses show that high R&D-intensive firms implement the inventory leanness strategy particularly when their employees are more efficient and have recently experienced minimum variation in inventory turnover.

Next, we study the joint effect of R&D intensity and inventory leanness on a firm's financial and market performance. While we find a negative impact of R&D intensity on financial performance, interestingly, this negative effect lessens when the firm follows an inventory leanness strategy. This finding suggests that the loop that inventory leanness creates from cost savings helps high R&D-intensive firms minimize the risk of getting fewer returns from R&D activities. Moreover, R&D intensity exhibits a positive association with a firm's market value, which becomes stronger in the context of inventory leanness. This finding implies that the market participants value R&D spending more favorably when a firm shows a proactive approach to cost-saving measures. Therefore, this study's findings indicate that the implementation of inventory leanness by high R&D-intensive firms benefits them in multiple ways.

The remainder of this paper is organized as follows. The next section, Section 2, reviews the relevant literature, drawing connections between R&D spending, lean inventory strategy, and their combined effects on firm performance. Section 3 describes the methodology, including the data sources, sample, and analytical techniques. Section 4 presents the empirical results, offering a detailed analysis of the findings. Section 5 concludes the paper by summarizing the key findings, highlighting the contributions to the existing literature, and suggesting directions for future research.

2. Literature review and hypotheses

Innovation activities are crucial for a firm to grow and maintain profitability. Until recently, it was common for firms to confine their innovation activities within and rely exclusively on internal resources to generate new ideas through R&D, transform ideas into products, and produce and commercialize them to the market, a model known as "closed innovation" (Bigliardi et al., 2020; Chesbrough, 2003). However, firms are now opening up their innovation processes and combining internally and externally developed technologies to create value. This notion is known as "open innovation" (Chesbrough, 2003). However, firms are often forced to engage in open innovation activities due to market competition, which may have a significant financial cost (Bigliardi et al., 2020). Caputo et al. (2016) study the relationship between open innovation initiatives and financial performance. They document that patent growth is not associated with implementing open innovation activities. Further, while they find a positive association between open innovation and sales growth, profitability decreases with open innovation practices. This evidence suggests that increasing sales from open innovation does not exceed the costs of such an innovation approach.

The literature on the financial implications of closed innovation activities also supports the above notion about the riskiness of R&D activities. For instance, Artz et al., (2010) find a positive association between R&D spending and number of patents, however, the association between patents and profitability is negative. As the authors explained, one possible reason for this negative effect on profitability is that not all patents result in commercially viable products or services. In such a case, the R&D spending hurts firm profitability. Similarly, Leung and Sharma (2021) find a negative association between R&D intensity and the firm's profitability in the form of sales growth and net assets per share. Other studies also document the adverse effects of R&D investment on operating performance (e.g., Vithessonthi and Racela, 2016). Perhaps that's why Schuhmacher et al. (2013, p. 1137) state that "there is no best [open or closed] innovation model for R&D that is generally superior and, thus, a basis for higher R&D productivity".

Thus, the extant literature implies that R&D spending is associated with risks and uncertainties, as it may not generate positive returns for the firm. As such, we propose that high-R&D-intensive firms put cost-saving mechanisms in place, such as inventory leanness, to offset the risk of receiving low (or no) returns from innovation activities.

The following evidence drives us to believe that high R&D intensity may lead firms to follow an inventory leanness approach. Inventory leanness involves maintaining the lowest possible inventory levels to minimize associated expenses, including storage, insurance, and obsolescence risks. According to the resource orchestration theory (ROT), managers play a vital role in identifying resources and transforming them into capabilities that align with the existing business strategies. Accordingly, managers orchestrate a set of resources that create value and ensure efficiency, influencing firm performance positively (Queiroz et al., 2022). For instance, Nawanir et al. (2020) show that lean production has greater effects when combined with other resources and that portfolio results in operational flexibility and competitive advantages. Consistent with this argument, Elking et al. (2017) report a positive effect of inventory leanness on the performance of U.S. manufacturing firms, and this effect is more substantial in the context of a high degree of financial dependence between suppliers and the focal firm. Barker et al. (2022) explore how the leanness of inventories in supplier firms impacts the focal firm's performance. The study reveals that the focal firm's financial performance is indeed affected by the leanness of the supplier firms' inventories, but this effect is contingent on the inventory leanness of the focal firm itself. Other research also confirms the positive implications of inventory leanness for firm performance (e.g., Haque, 2023; Koumanakos, 2008).

Given that inventory leanness reduces wastage and enhances a firm's asset utilization efficiency and that R&D projects may generate lower-than-expected financial returns, we predict that high R&D-intensive firms would favor an inventory leanness approach. We also expect that the cost savings from inventory leanness will positively moderate the association between R&D intensity and firm performance. Accordingly, we develop and test the following hypotheses.

H1. : Higher R&D intensity is associated with a greater likelihood of implementing an inventory leanness approach.

H2. : Inventory leanness will positively moderate the association between R&D intensity and firm performance.

3. Methodology

3.1. The sample

This study's sample comprises manufacturing firms in the U.S. within the SIC codes 2000–3999 from 1992 to 2019. Compustat provides us with the required data. Observations that have missing values on R&D expenditure are deleted. After dropping observations containing missing values for other required variables, the final dataset comprises 43,634 firm-year observations representing 4800 distinct firms. However, the sample size varies in different tests based on the specific data requirements for each analysis.

3.2. Variables

Inventory leanness, denoted as *Leanness*, is computed by conducting a yearly regression analysis for each industry (3-digit SIC), where the dependent variable is the natural logarithm of inventories, and the independent variable is the natural logarithm of sales. This is formulated in Eq. (1). This measurement approach aligns with the methodology introduced by Eroglu and Hofer (2011). One advantage of calculating inventory leanness based on Eq. (1), rather than traditional measures such as inventory turnover, is that it accounts for economies of scale and characteristics specific to an industry. Therefore, this method attributes within industry variations in the inventory-sales relationship to their differential inventory policies.

$$Inventory_{ift} = \alpha + \beta_{it}\ Sales_{ift} + \epsilon_{ift} \quad (1)$$

where *Inventory* represents the logarithm of firm *f*'s average of year *t* and *t-1*'s inventory in industry *i*. *Sales* denotes the logarithm of firm *f*'s sales in year *t* in industry *i*. To accommodate log transformation, zero values are replaced with 0.001, consistent with the approach employed by Chen et al. (2005). The residuals derived from Eq. (1) constitute the foundation for our *Leanness* variable. For ease of interpretation, we multiply the residuals by −1 so that positive (negative) values represent leanness (non-leanness). Then, we create an indicator variable - *ELI* - which is set to 1 (0) for positive (negative) values of *Leanness*.

A firm's R&D intensity, labeled *RD Intensity*, is determined by dividing its research and development spending by total assets. Firm performance is assessed through two metrics: return on assets (*ROA*), which proxies for financial/accounting performance, and *Tobin's Q* for market performance/value. *ROA* is the firm's net profit scaled by total assets. *Tobin's Q* is calculated as the total market value of equity and total assets minus the total of common shareholders' equity and deferred tax, scaled by total assets.

We employ a logit regression to examine if higher R&D intensity leads to a greater probability for firms to follow an inventory leanness approach. Logit regression is appropriate when the dependent variable is a dummy variable and, in our case, the proxy for inventory leanness, *ELI*, is a dummy one. However, we employ an ordinary least squares regression to examine the joint effect of R&D intensity and inventory leanness on firm performance because the dependent variable in that regression is a continuous variable.

3.3. The model

We estimate a logit regression, shown in Eq. (2), to test the implications of R&D intensity for inventory leanness.

$$ELI_t = \alpha + RD\ Intensity_{t-1} + \ Controls_{t-1} + \epsilon \quad (2)$$

where *ELI* is an indicator variable that proxies for inventory leanness and *RD Intensity* for the level of spending in research and development. The regression uses one-year lagged values of *RD Intensity* to estimate inventory leanness in the current year to avoid any reverse causality concerns. A one-year lag is also applied for the control variables.

Eq. (2) includes the following control variables: property, plant, and equipment scaled by total assets (*PPE*), selling, general, and administrative expenses scaled by total sales (*SGA*), free cash flow (*FCF*), long-term debt scaled by total assets (*Leverage*), log of total assets (*Firm Size*), total sales scaled by number of employees (*Productivity*), and market competition (*HHI*). The Appendix defines these variables. These control variables follow those in the prior research determining a firm's decision about inventory leanness (Kim and Na, 2022; Na et al., 2021).

We run an ordinary least squares regression, shown in Eq. (3), to examine the interaction effect of R&D intensity and inventory leanness on firm performance.

$$ROA/Tobin's\ \ Q_t = \alpha + RD\ Intensity_{t-1} + ELI_t + RD\ Intensity_{t-1} \times ELI_t + \ Controls_{t-1} + \epsilon \quad (3)$$

where *ROA* and *Tobin's Q* proxy for firm performance, *ELI* for inventory leanness, and *RD Intensity* for the research and development spending. Eq. (3) controls for other determinants of firm performance that include *Firm Size*, *Leverage*, *Capex*, and *Fin. Constraints*. *Capex* equals the firm's capital expenditure divided by total assets. Financial constraints (*Fin. Constraints)* is calculated following Whited and Wu (2006), and its detailed definition is provided in the Appendix. All other variables are defined earlier.

3.4. Descriptive statistics and correlation

The summary statistics in Table 1 show an average *Leanness* of −0.2157, implying that the average firm keeps inventory greater than predicted by sales volume. The average *ELI* is 0.3786, suggesting that 37.86% of the sample firms follow an inventory leanness strategy. *RD Intensity* has a mean of 0.0892, indicating that the average firm's spending in research and development equals 8.92% of total assets. The average firm has a 15.59% long-term debt in the capital structure and a negative return on assets.

Table 2 presents the correlation matrix. Our point of interest is the significantly positive correlation of *RD Intensity* with *ELI*, which implies that higher R&D intensity leads to a greater probability of inventory leanness. The correlation between the control variables is moderate, with a highest of 0.4278 between *FCF* and *Firm Size*. Thus, multicollinearity is not likely to be an issue in the multivariate regressions.

4. Empirical results and discussion

4.1. Main results

Table 3 presents the results estimated based on Eq. (2), which examines if R&D intensity is related to inventory leanness. The control variables are not included in Column 1 but in Column 2. The coefficient of *RD Intensity* in both columns is significantly positive (at the 1% level), suggesting a greater likelihood of implementing an inventory leanness strategy in firms with greater R&D intensity. Regarding the magnitude, firms with *RD Intensity* at the 75th percentile are 15% [(0.1120 – 0.0164) * 1.6175 = 15%] more likely than those with *RD Intensity* at the 25th percentile to follow an inventory leanness strategy. This finding supports our first hypothesis (H1) that higher R&D intensity is associated with a greater likelihood of implementing an inventory leanness approach.

The control variables exhibit signs in directions similar to those found in the extant literature. For instance, the likelihood of inventory leanness increases with increased production resources (i.e., *PPE*) and *FCF*. A firm with high *PPE* reflects the availability of production resources that help improve operational outcomes, such as inventory leanness (Kim and Na, 2022). *FCF* relates to a firm's liquidity and financial stability, guiding the adoption of lean inventory (Na et al., 2021). The coefficient of *Firm Size* is negative and significant, confirming the finding of Na et al. (2021) that it is difficult for larger firms to follow a lean approach. *Productivity* loads a significantly positive coefficient, confirming that firms with high productivity find it feasible to follow an

Table 1
Descriptive statistics: This table reports descriptive statistics for variables used in this study, which covers the sample period from 1992 to 2019. All continuous variables are winsorized at the 1% and 99% levels. The definitions of all the variables are provided in the Appendix.

	Obs	Mean	SD	p25	p75
Leanness $_t$	43,634	-0.2157	1.0913	-0.6030	0.2054
ELI $_t$	43,634	0.3786	0.4850	0.0000	1.0000
RD Intensity $_{t-1}$	43,634	0.0892	0.1226	0.0164	0.1120
PPE $_{t-1}$	43,634	0.2047	0.1561	0.0840	0.2880
SGA $_{t-1}$	43,634	0.7649	2.0374	0.1876	0.5055
FCF $_{t-1}$	43,634	0.6819	0.4658	0.0000	1.0000
Leverage $_{t-1}$	43,634	0.1559	0.2073	0.0000	0.2367
Firm Size $_{t-1}$	43,634	5.2990	2.5821	3.4237	7.0886
Productivity $_{t-1}$	43,634	264.9834	232.5566	130.6031	314.4297
HHI $_{t-1}$	43,634	0.0295	0.1143	0.0000	0.0026
ROA $_t$	43,634	-0.1268	0.5351	-0.0955	0.0784
Tobin's Q $_t$	31,469	2.1335	2.5975	0.8481	2.3135
Capex $_{t-1}$	43,634	0.0449	0.0424	0.0169	0.0582
Fin. Constraints $_{t-1}$	43,634	-0.2269	0.1381	-0.3190	-0.1449
Prod. Efficiency $_{t-1}$	43,420	-0.0082	0.8884	-0.4438	0.0862
SD5 Inv. Turnover $_{t-1}$	30,548	24.0511	472.3891	0.8048	5.4433

Table 2
Correlation: This table presents a pairwise correlation matrix of the variables used in Equation (2). All variables are defined in the Appendix. The symbol * denotes statistical significance at a 5% level or better.

		1	2	3	4	5	6	7	8	9
1	ELI	1								
2	RD Intensity	0.0412*	1							
3	PPE	0.0145*	-0.2283*	1						
4	SGA	-0.0079	0.4271*	-0.1360*	1					
5	FCF	0.0292*	-0.3727*	0.1973*	-0.3378*	1				
6	Leverage	-0.0165*	-0.0643*	0.1760*	-0.0081	0.0625*	1			
7	Firm Size	-0.0818*	-0.3657*	0.2254*	-0.2868*	0.4278*	0.1655*	1		
8	Productivity	0.0224*	-0.1171*	-0.0343*	-0.1999*	0.1689*	0.0155*	0.3502*	1	
9	HHI	-0.0115*	-0.1218*	0.0559*	-0.0701*	0.1244*	0.0558*	0.3012*	0.0315*	1

Table 3
R&D intensity and inventory leanness: This table reports regression results on the association between R&D intensity (*RD Intensity*) and inventory leanness (*ELI*). *RD Intensity* is defined as the firm's research and development spending divided by total assets. *ELI* is an indicator variable set to 1 for inventory leanness and 0 otherwise. All other variables are defined in the Appendix. Heteroscedasticity-robust standard errors are in parentheses, clustered by firm. *p < 0.1; **p <0.05; ***p <0.01.

	(1)	(2)
	ELI $_t$	ELI $_t$
RD Intensity $_{t-1}$	0.6769***	1.6175***
	(0.1639)	(0.2052)
PPE $_{t-1}$		0.4115**
		(0.1954)
SGA $_{t-1}$		0.0110
		(0.0112)
FCF $_{t-1}$		0.2847***
		(0.0408)
Leverage $_{t-1}$		-0.1051
		(0.0992)
Firm Size $_{t-1}$		-0.1235***
		(0.0133)
Productivity $_{t-1}$		0.0009***
		(0.0001)
HHI $_{t-1}$		0.0564
		(0.2678)
Year FE	No	Yes
Industry FE	No	Yes
Observations	43,634	43,634
Pseudo R2	0.0013	0.0550

inventory leanness strategy (Kim and Na, 2022).

4.2. Cross-sectional analyses

In this section, we consider two scenarios in which a firm might logically choose to embrace a lean inventory strategy: when it (i) exhibits high production efficiency and (ii) experiences minimum fluctuations in inventory turnover. Production efficiency indicates a firm's capacity to generate sales revenue by utilizing its PPE relative to the industry peers. Accordingly, a high production efficiency indicates more efficiency (Modi and Mishra, 2011). As such, we expect high production efficiency to spur R&D-intensive firms to implement inventory leanness. Similarly, we expect a low fluctuation in inventory turnover to instigate R&D-intensive firms to implement an inventory leanness strategy. This is because low fluctuation in inventory turnover across periods indicates stable demand for the firm's products. When the demand is steady, the firm does not need to keep much slack in its inventories.

We define *Production Efficiency* as the firm's sales divided by total production resources, calculated following Modi and Mishra (2011), and create an indicator variable – *High Prod. Efficiency* – which is set to 1 if *Production Efficiency* exceeds the industry median, 0 otherwise. The fluctuation in inventory turnover is determined by calculating the standard deviation of the firm's inventory turnover in the past five years, where inventory turnover is characterized by the ratio of the cost of sales to the average of opening and closing inventories. Then, an indicator variable – *Low SD5 Inv. Turnover* – is created, which takes a value of 1 (0) if the standard deviation is less than (greater than or equal to) the industry median. These dummy variables are then interacted with *RD Intensity* in Eq. (2). Table 4 presents the relevant results.

The coefficients of *RD Intensity* and *RD Intensity* × *High Prod. Efficiency* in Column 1 is significantly positive, indicating that R&D-intensive firms with higher production efficiency are more likely to implement an inventory leanness strategy. The individual coefficient of *High Prod. Efficiency* is also positive and significant, implying that production-efficient firms are likelier than others to choose an inventory leanness strategy.

Similarly, the coefficients of *RD Intensity* and *RD Intensity* × *Low SD5*

Table 4
Cross-sectional tests: This table reports regression results on the association between R&D intensity and inventory leanness after incorporating two moderators relating to firm characteristics. *RD Intensity* is defined as the firm's research and development spending divided by total assets. *ELI* is an indicator variable set to 1 for inventory leanness and 0 otherwise. *High Prod. Efficiency* is a dummy variable set to 1 if the firm's production efficiency in a year is greater than the industry median, and 0 otherwise. *Low SD5 Inv. Turnover* is a dummy variable set to 1 if the firm's standard deviation of inventory turnover in the past five years is less than the industry median, and 0 otherwise. All other variables are defined in the Appendix. Heteroscedasticity-robust standard errors are in parentheses, clustered by firm. *p < 0.1; **p <0.05; ***p <0.01.

	(1)	(2)
	ELI $_t$	ELI $_t$
RD Intensity $_{t-1}$	0.6209**	1.4792***
	(0.2586)	(0.2136)
High Prod. Efficiency $_{t-1}$	0.2446***	
	(0.0544)	
RD Intensity $_{t-1}$ × High Prod. Efficiency $_{t-1}$	1.5407***	
	(0.2932)	
Low SD5 Inv. Turnover $_{t-1}$		-0.7102***
		(0.0566)
RD Intensity $_{t-1}$ × Low SD5 Inv. Turnover $_{t-1}$		0.8001**
		(0.3381)
PPE $_{t-1}$	1.1444***	0.2722
	(0.2124)	(0.1907)
SGA $_{t-1}$	0.0350***	0.0073
	(0.0111)	(0.0111)
FCF $_{t-1}$	0.2562***	0.3477***
	(0.0408)	(0.0411)
Leverage $_{t-1}$	-0.1189	-0.1117
	(0.0998)	(0.0981)
Firm Size $_{t-1}$	-0.1038***	-0.0970***
	(0.0136)	(0.0134)
Productivity $_{t-1}$	0.0008***	0.0009***
	(0.0001)	(0.0001)
HHI $_{t-1}$	-0.0110	0.0997
	(0.2675)	(0.2757)
Year FE	Yes	Yes
Industry FE	Yes	Yes
Observations	43,634	43,634
Pseudo R2	0.0601	0.0682

Inv. Turnover in Column 2 is significantly positive, implying a higher possibility of implementing an inventory leanness strategy by R&D-intensive firms when they recently experienced low fluctuations in inventory turnover. Interestingly, the coefficient of *Low SD5 Inv. Turnover* is significantly negative. It suggests that firms with low change in inventory turnover are less likely to follow inventory leanness (i.e., they tend to keep more inventories). However, the significantly positive interaction of *RD Intensity* and *Low SD5 Inv. Turnover* suggests that firms with low fluctuation in inventory turnover tend to follow inventory leanness when they spend more on R&D, which aligns with the R&D effect of inventory leanness found in Table 3.

4.3. Implications of inventory leanness for the performance of R&D intensive firms

Since Table 3 results suggest a higher likelihood of inventory leanness for firms with greater R&D intensity, a subsequent natural question is whether adopting inventory leanness pays them off. Since R&D does not contribute to profitability when it fails to precede commercially variable products, the cost savings from inventory leanness may help R&D-intensive firms report better performance. To test this, we estimate Eq. (3) and present the results in Table 5. The dependent variable is *ROA* (*Tobin's Q*) in Column 1 (2).

The negative and significant coefficient of *RD Intensity* in Column 1 suggests low *ROA* in firms exhibiting high R&D intensity. This observation aligns with the perspective that an emphasis on closed or open innovation may not necessarily lead to commercially variable products or services, impacting firm performance negatively (Caputo et al., 2016; Leung and Sharma, 2021). We see a significantly positive coefficient of *ELI*, suggesting better financial performance in firms that follow inventory leanness than their non-lean counterparts. This finding confirms the cost-saving view of inventory leanness presented in prior research (e.g., Elking et al., 2017; Haque, 2023). The coefficient of our point-of-interest variable – *RD Intensity* × *ELI* – is positive and significant. As the coefficient of *RD Intensity* is negative, a positive coefficient of this interaction term indicates that inventory leanness reduces the adverse effect of R&D spending on firm *ROA*. The combined coefficient of *RD Intensity* and *RD Intensity* × *ELI* remains negative and significant ($-1.2973 + 0.2038 = 1.0935$, $F = 139.27$, $p = 0.01$), suggesting that inventory leanness partially mitigates the adverse effects of R&D expenditure. Thus, the results in Column 1 underscore the benefits of inventory leanness for R&D-intensive firms.

The results in Column 2 further emphasize the benefits of inventory leanness for high R&D spending firms from a market performance point of view. Interestingly, we see a significantly positive coefficient of *RD Intensity* here, suggesting that the market perceives investments in R&D as a good signal. This could be attributed to the long-term nature of R&D activities as they generate returns after some years of the actual spending, a dimension that short-term performance measures, such as *ROA* in Column 1, could not capture. Like that in Column 1, *RD Intensity* × *ELI* in Column 2 loads a significantly positive coefficient. It indicates that the market value addition effect of R&D becomes more prominent when the firm adopts an inventory leanness strategy. Overall, Table 5 results demonstrate that adopting an inventory leanness strategy helps firms mitigate the short-term adverse effect of R&D spending on financial performance while fostering long-term market value, supporting our hypothesis (H2) of a positive moderating effect of inventory leanness on the association between R&D intensity and firm performance. They also support the perspective of ROT that managers orchestrate a set of resources that create value and ensure the firm's overall efficiency, influencing performance positively (Queiroz et al., 2022).

Table 5
The impact of R&D intensity and inventory leanness on firm performance: This table reports regression results on the interaction effect of R&D intensity (*RD Intensity*) and inventory leanness (*ELI*) on firm performance. *RD Intensity* is defined as the firm's research and development spending divided by total assets. *ELI* is an indicator variable set to 1 for inventory leanness and 0 otherwise. *ROA* equals net profit divided by total assets. *Tobin's Q* is defined as the market value of equity plus total assets minus common shareholders' equity minus deferred tax, divided by total assets. All other variables are defined in the Appendix. Heteroscedasticity-robust standard errors are in parentheses, clustered by firm. *p < 0.1; **p <0.05; ***p <0.01.

	(1)	(2)
	ROA_t	$Tobin's\ Q_t$
$RD\ Intensity_{t-1}$	-1.2973***	2.1124***
	(0.0737)	(0.4320)
ELI_t	0.0211**	0.2392***
	(0.0082)	(0.0551)
$RD\ Intensity_{t-1} \times ELI_t$	0.2038**	1.3933**
	(0.0982)	(0.5564)
$Firm\ Size_{t-1}$	-0.0490***	-0.1696***
	(0.0074)	(0.0288)
$Leverage_{t-1}$	-0.1610***	0.5667***
	(0.0238)	(0.1945)
$Capex_{t-1}$	-0.1564*	2.2454***
	(0.0818)	(0.5668)
$Fin.\ Constraints_{t-1}$	-2.4824***	-2.3192***
	(0.1591)	(0.6236)
ROA_{t-1}		-1.8701***
		(0.1285)
Year FE	Yes	Yes
Industry FE	Yes	Yes
Observations	43,634	31,469
R-squared	0.3639	0.2985

5. Conclusion

This study investigates whether a firm's degree of R&D intensity relates to its inventory leanness strategy and, if so, the combined effects of R&D spending and inventory leanness on firm performance. Drawing on a contextual perspective of organizational processes and combining the views of innovation and resource orchestration theories, we hypothesize that since R&D efforts may not result in new products/services, firms with high R&D spending are more inclined than others to adopt an inventory leanness strategy. This inclination is linked to the substantial cost reduction associated with that strategy. We further hypothesize that the cost reduction from inventory leanness would help them cover the risks of getting low returns from R&D spending. Results based on manufacturing firms in the U.S. support both the hypothesis.

While inventory leanness carries risks regarding failure to fulfill a sudden increase in product demand, our results suggest that it is not a concern for our sample firms as firms with inventory leanness report better financial- and market performance than those with non-leanness. In contrast, we find investment in R&D activities a risk factor because it reduces the firm's financial performance. Our results jointly suggest that inventory leanness offsets the risk of receiving less returns from investments in R&D activities. Thus, this study's findings indicate that the managers of firms with high R&D spending opt for inventory leanness as a cost-saving and mitigating strategy to address the uncertainties associated with receiving returns from their R&D investments.

The contribution of this study is two-fold. Firstly, it advances our understanding of the internal attributes that drive a firm to opt for a lean inventory strategy. While prior research has primarily concentrated on the consequences of inventory (non)leanness, such as performance (e.g., Barker et al., 2022; Elking et al., 2017; Roh and Lee, 2013), there has been limited knowledge regarding when or in what contexts firms choose to employ an inventory leanness strategy. This study provides insight into the fact that firms with higher expenditures on R&D are more inclined than their counterparts to adopt an inventory leanness strategy. Secondly, although it is recognized that R&D spending carries inherent risks and can potentially diminish firm performance, there have been limited insights into how managers respond to potential losses in this regard. This study sheds light on this by demonstrating that the managers of R&D-intensive firms adopt inventory leanness as a strategic approach that offsets, to some extent, the uncertainties associated with returns from R&D investments.

This study's findings are relevant to investors' decision-making. While investors might view managers' R&D spending as potentially opportunistic and indicative of agency issues, this study suggests that the managers put alternatives in place even when R&D spending appears opportunistic and lacks evident economic benefits. Thus, investors are advised to consider more than just the potential downside of R&D spending when evaluating whether to buy, hold, or sell a firm's shares.

The insights this study documents can be extended further in the following ways. Future research may interview managers to inquire whether they consider the firms' R&D spending when formulating their inventory strategies. Such an inquiry will help test the validity of this study's findings. Another avenue for future research is to employ a machine learning approach, such as "transfer learning" which underscores the utilization of learning from one task (such as the benefits of inventory leanness) to improve performance on another task (such as R&D efficiency) (Ali et al., 2023), to comprehend further our understanding of the interplay among R&D intensity, inventory leanness, and firm performance. Future research can also examine the relationship between R&D intensity and inventory leanness across industries based on characteristics such as competition and life-cycle stages. We cannot test such a possibility because measuring industry-level competition and identifying life-cycle stages required survey data (Kallunki and Silvola, 2008). A test of this study's models and findings in non-US contexts with unique regulatory environments and supply chain characteristics will also be worth researching.

Funding

This project was funded by Abu Dhabi University Internal Research Grants 2022/2023, Grant #19300819.

Ethical Statement

This is not applicable as this research does not include any animals or humans as subjects.

CRediT authorship contribution statement

Md Reiazul Haque: Conceptualization, Software, Writing – original draft, Formal analysis, Methodology, Project administration, Writing – review & editing. **Md Abubakar Siddique:** Writing – review & editing, Funding acquisition, Resources, Writing – original draft. **Amit Kumar:** Writing – review & editing, Resources, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix. : Variable definition

Variable name	Definition
Leanness	Inventory leanness, calculated as the residual of the following equation estimated for each 3-digit SIC industry and year: $Inventory_{ift} = \alpha + \beta_{it}Sales_{ift} + \epsilon_{ift}$
ELI	Dummy variable set to 1 for firms with a lean inventory strategy ($Leanness \times -1$ is greater than zero), 0 otherwise
RD Intensity	Research and development expenditure/total assets
PPE	Net property, plant, and equipment/total assets
SGA	Selling, general and administrative expenses/total sales
FCF	Dummy variable set to 1 if free cash flow is positive, 0 otherwise. Free cash flow is calculated as operating income before depreciation minus the change in working capital minus the change in capital expenditure. Change in working capital = trade receivable plus total inventories plus other current assets minus trade payable minus other current liabilities.
Leverage	Long-term debt/total assets
Firm Size	Log of total assets
Productivity	Total sales/number of employees
HHI	Herfindahl concentration index, i.e., the sum of squared market shares of firms in an industry
ROA	Net profit/total assets
Tobin's Q	Market value of equity plus total assets minus common shareholders' equity minus deferred tax, divided by total assets
Capex	Capital expenditure/total assets
Fin. Constraints	Following Whited and Wu (2006), financial constraints risk is measured as: $-0.091(CF) -0.062(DIVPO) +0.021(LTD) -0.044(TA) +0.102(ISG) -0.035(SG)$, where *CF* is the ratio of earnings before extraordinary items plus depreciation and amortization of total assets; *DIVPO* equals 1 if the firm pays cash dividends, 0 otherwise; *LTD* is the ratio of long-term debt to total assets; *TA* is the log of total assets; *ISG* is the firm's 3-digit SIC industry sales growth; and *SG* is the firm's sales growth. All these variables are measured at year t.
High Prod. Efficiency	Dummy variable set to 1 if production efficiency in a year is greater than the industry median, 0 otherwise, where production efficiency is calculated as the ratio of sales-to-plant, property, and equipment for each firm compared to its industry, calculated following Modi and Mishra (2011).
Low SD5 Inv. Turnover	Dummy variable set to 1 if the standard deviation of inventory turnover in the past five years is lower than the industry median, 0 otherwise, where inventory turnover is calculated as the cost of goods sold divided by an average inventory of finished goods.

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