








Determinants of R&D investment under Uncertainty: An Empirical Study of Saudi Firms

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ABSTRACT

This study aims to examine the financial determinants of research and development (R&D) investment in Saudi industrial firms, with particular emphasis on periods of economic crises. The 2008 Global Financial Crisis and the COVID-19 pandemic are employed as representative examples of major economic shocks to assess firms' innovation responses. To achieve this objective, the analysis incorporates firm-specific variables using panel data for a sample of thirty industrial firms over the period 2007–2020. The sample selection is based on firms' strategic engagement in R&D activities and the critical contribution of the industrial sector to the national economy. The dataset, covering fourteen years, was compiled from audited financial statements of the selected firms, obtained from their official websites. The study adopts a purposive sampling approach and an explanatory (causal) research design, employing quantitative data within a multiple regression framework. Using STATA for empirical analysis, the study utilizes one dependent variable R&D investment, measured as the ratio of R&D expenditure to total assets and eight independent variables: cash, sales growth rate, gross profit from sales, return on assets, return on equity, internal financing rate, external financing rate, and the debt-to-equity ratio. The results reveal a statistically significant positive relationship between sales growth rate, gross profit from sales, return on assets, and internal financing, and R&D investment. Conversely, the findings indicate a negative relationship between cash holdings, return on equity, external financing, and the debt-to-equity ratio, and R&D investment. Although crises explains only a small share of R&D variation ($R^2 \approx 13\%$), financial variables consistently demonstrate far greater explanatory power (87%), confirming that firms' financial conditions are the key drivers of R&D investment in times of economic turmoil. Finally, the study recommends that Saudi industrial firms adopt optimal business portfolio diversification strategies to reduce exposure to crisis-related risks and mitigate their adverse effects. To enhance their investment portfolios, firms should move beyond traditional income sources and diversify into alternative, non-interest-based revenue streams.

Keywords: R&D, Financial Determinants, Financial Performance

INTRODUCTION

Research and Development (R&D) investment is widely viewed as a fundamental engine of economic growth and long-term development (Alam et al., 2019). A number of studies, including E. C. Wang(2010), suggest that countries maintaining sustained levels of R&D spending tend to achieve higher productivity and stronger knowledge accumulation, which ultimately supports economic expansion. For this reason, a large body of literature has focused on identifying the key factors that drive firms' and countries' R&D investment decisions (Barge-Gil & López, 2014).

From a theoretical standpoint, different perspectives have been used to explain variations in R&D behavior. The Schumpeterian view, for example, places emphasis on market structure and competition as central forces shaping innovation. In contrast, the resource-based view shifts attention to firm-level capabilities, arguing that internal resources and accumulated knowledge are critical for sustaining R&D activities (Lai et al., 2015). Another stream of research adopts a behavioral perspective, highlighting how managerial decisions and firms' responses to uncertainty influence investment patterns (Lewellyn & Bao, 2015). These approaches collectively suggest that R&D investment is not driven by a single factor, but rather by a combination of structural, organizational, and strategic considerations.

Beyond firm-level characteristics, the broader institutional environment also plays a significant role. E. C. Wang(2010) points out that supportive institutional conditions can enhance innovation by reducing barriers and encouraging investment in new technologies. In practice, well-functioning institutions tend to facilitate collaboration, improve access to information, and promote knowledge exchange, all of which contribute to stronger R&D performance (Wu et al., 2016). Similarly, Lai et al. (2015) argue that innovation outcomes are shaped by the interaction between firm-specific attributes and the institutional context in which firms operate.

In addition to these structural and institutional factors, recent research has increasingly considered the role of uncertainty in shaping R&D decisions. In this study, uncertainty is associated with major economic shocks, particularly the 2008 Global Financial Crisis and the COVID-19 pandemic. These events created significant volatility in economic conditions and policy environments, making investment decisions more complex and risky. Under such circumstances, firms often face tighter financial constraints and may become more cautious in allocating resources to long-term projects such as R&D.

To capture this dimension, the literature commonly relies on indicators such as country risk measures or political changes (Swanpitak et al., 2020). Building on the framework proposed by Carrière-Swallow and Céspedes(2013), this study focuses on economic policy uncertainty (EPU), which reflects the degree of unpredictability surrounding government policies that affect economic performance. By incorporating EPU, the analysis aims to better understand how uncertainty influences firms' willingness and ability to invest in R&D activities.

Theoretically, similarly, high uncertainty combined with investment irreversibility leads firms to postpone investment decisions (Carrière-Swallow & Céspedes, 2013). This is particularly relevant for R&D due to its high sunk costs and intangible outcomes (Holmstrom, 1989). Furthermore, EPU increases risk aversion, reduces cash flows, and restricts access to external financing, thereby discouraging long-term investment and shifting firms toward short-term strategies.

Empirically, this evidence suggests that higher EPU reduces investment, output, and employment (Chen et al., 2019), while simultaneously increasing the value of waiting Hud and Hussinger (2015). Although some studies report a positive relationship between EPU and R&D Tajaddini and Gholipour, 2020), the majority of empirical evidence, however, indicates a negative effect (Li et al., 2020). Collectively, these findings suggest that firms tend to delay investment under uncertainty due to increased cash flow risk and limited access to external financing (Huang et al., 2015).

With an emphasis on important financial variables such as cash holdings, sales growth rate, gross profit on sales, return on assets, return on equity, internal financing rate, external financing rate, and the debt-to-equity ratio, this study empirically investigates the factors that influence R&D investment at the firm level. Firm-level evidence is still scarce, especially in Saudi Arabia, despite a wealth of studies on R&D investment under uncertainty in developed economies like the US and Europe. Furthermore, current research frequently ignores the ways in which uncertainty and financial factors interact to influence R&D choices. This study offers fresh empirical

data on how Saudi companies react to uncertainty in their R&D investment behavior in order to close these disparities.

By concentrating on Saudi Arabian companies, this study adds to the body of knowledge and makes a number of notable improvements over other studies. First, it highlights businesses in the industrial sector, which is vital to the Saudi economy's financial and economic stability. Second, by analyzing the role of financial variables in molding organizations' resilience, this study offers a fresh perspective, since many instances of firm failure under uncertain conditions are intimately tied to flaws in financial management. Third, it looks into how these financial factors affect businesses' capacity to manage risk, offering useful information about tactics that encourage investment activity.

Finally, it contributes to the achievement of broader economic objectives, such as those outlined in Saudi Vision 2030, by providing evidence-based recommendations to strengthen firm resilience and competitiveness.

Accordingly, this study offers new and robust empirical evidence on the relationship between financial determinants and investment in research and development (R&D), thereby addressing an important gap in the existing literature.

This paper is structured into five sections. The first section includes the background of our study, including research and development (R&D). The following section deals with a review of the literature based on the most recent empirical data, hypothesis construction, and the Conceptual Model for research and development (R&D) in Saudi Firms design. The third section is Data, Methodology, and regression model design. The fourth section is devoted to Analysis and Findings. The final section of this study provides the concluding remarks, discusses policy implications, and highlights directions for future research.

LITERATURE REVIEW AND HYPOTHESES

Cash (cash)

Previous studies show that cash availability plays a critical role in determining R&D investment. Gugler et al. (2004) emphasize that cash flow and financial flexibility influence firms' ability to invest in R&D. Similarly, Wintoki (2016) find that R&D activities are closely linked to higher cash holdings, suggesting that firms accumulate cash to support innovation. In addition, Xu and Sim (2018) demonstrate that firms with higher asset liquidity tend to invest more in R&D and achieve greater innovation output, highlighting liquidity as a key driver of R&D investment.

Based on the reviewed literature, the following hypothesis is formulated:

H1: Cash has a positive and statistically significant effect on R&D investment.

Sales growth rate (SGR)

Himmelberg and Petersen (1994) show that firms with higher sales growth tend to have better access to internal financing, which supports greater R&D investment. Similarly, Park (1995) finds that sales-driven R&D significantly enhances productivity at both domestic and international levels, indicating that growing firms are more likely to invest in innovation. In addition, Brzozowski (2008) highlights that factors linked to sales performance, such as the cost of capital and expected returns, influence R&D expenditure, reinforcing the role of sales growth in shaping investment decisions.

Based on the reviewed literature, the following hypothesis is formulated:

H2: Sales growth rate has a Positive and statistically significant effect on R&D investment

Gross profit on sales (GPS)

Several studies highlight financial performance, particularly profitability and sales, as key drivers of R&D investment. Balkin and Gomez-Mejia (1984) show that sales volume and profitability significantly influence the

level and structure of R&D-related incentives, reflecting a strong link between financial health and innovation spending. Similarly, Howe and McFetridge (1976) emphasize that R&D investment is shaped by product life cycle stages and turnover rates, which are closely associated with firm performance. Overall, firms with higher sales and stronger profitability are more likely to invest in R&D to sustain competitive advantage.

Based on the reviewed literature, the following hypothesis is formulated:

H3: Gross profit on sales has a Positive and statistically significant effect on R&D investment

Return on Assets (ROA)

Return on Assets (ROA) is a widely used indicator of firm performance, measuring a company's ability to generate profits from its assets (Sher & Yang, 2005). It reflects how efficiently firms utilize their financial resources, whether financed through equity or debt, to achieve growth (Artz et al., 2010).

Empirical evidence on the relationship between profitability and R&D investment is mixed. Lai et al.(2015) find that higher profitability increases R&D investment in some contexts, while showing a negative relationship in others. In contrast, Safitri et al.(2020) report a positive and significant impact of R&D on firm value, Tung and Binh(2022) confirm a positive relationship between R&D spending and firm performance measured by ROA.

Based on the reviewed literature, the following hypothesis is formulated:

H4: ROA has a Positive and statistically significant effect on R&D investment

Return on equity (ROE)

The determinants of R&D investment and their relationship with Return on Equity (ROE) have been widely examined across different contexts. Shin et al.(2009) show that firms occupying leading positions within global value chains tend to achieve higher performance, including ROE, suggesting that strategic positioning and R&D activities enhance financial outcomes.

In other contexts, Jakpar et al.(2018)find that dividend yield positively influences profitability, which is closely linked to ROE, while Jin et al. (2022) highlight ROE as a key factor affecting dividend policies, reflecting firms' investment efficiency and potential to sustain growth through R&D. Moreover, firm performance, as measured by ROE, is influenced by financial leverage and investment opportunities. Liu et al.(2021) further explore the threshold effects of ROE on earnings management and investment behavior, suggesting that beyond certain levels, ROE can influence managerial decisions related to R&D and investment strategies.

Based on the reviewed literature, the following hypothesis is formulated:

H5: Return on equity (ROE) has a Positive and statistically significant effect on R&D investment

Internal financing rate (IFR)

Internal financing plays a critical role in determining R&D investment, particularly under financial constraints. Fazzari et al. (1987) show that limited access to external capital restricts firms' ability to invest, increasing reliance on internal funds for activities such as R&D. Similarly, Himmelberg and Petersen (1994)find that internal resources are a key driver of R&D investment, especially in small high-tech firms where external financing is limited. In addition, Czarnitzki and Hottenrott (2011) demonstrate that financially constrained firms depend more on internal financing, highlighting its importance in sustaining innovation activities.

Based on the reviewed literature, the following hypothesis is formulated without a priori expectation regarding its sign:

H6: Internal financing rate has a Positive and statistically significant effect on R&D investment.

External finance rate (EFR)

External finance plays a crucial role in shaping R&D investment, particularly under conditions of financial constraints. Aghion et al.(2012)show that firms facing tighter credit constraints tend to reduce R&D spending, especially in sectors that rely heavily on external financing. Similarly, Peia and Romelli (2019) find that periods of credit tightening, such as the 2008–09 financial crisis, significantly decreased R&D investment, particularly among financially constrained firms. In contrast, Khan et al.(2021) highlight that improved financial development, which lowers the cost and increases the availability of external finance, can stimulate R&D activities. Overall, these findings emphasize the strong sensitivity of R&D investment to external finance conditions.

Based on the reviewed literature, the following hypothesis is formulated:

H7: The external finance rate has a negative and statistically significant effect on R&D investment

Debt to Equity ratio (DER)

Financial leverage, particularly measured by ratios such as the Debt-to-Equity Ratio (DER), plays an important role in shaping firms’ investment behavior, including R&D activities. Widiyanti and Elfina (2015) show that leverage significantly affects profitability, implying that financial structure influences firms’ capacity to undertake investments. Similarly, Kamar (2017) highlights that DER reflects a firm’s financial position and cost of financing, which may affect its willingness to invest in R&D.

In the banking context, Rachma and Syachrudin (2017) demonstrate that leverage is a key determinant of investment decisions, while Xu and Sim (2018) find that financial structure, including leverage, is closely associated with R&D intensity. Overall, these studies suggest that leverage influences R&D investment through its impact on financial capacity, risk, and the trade-off between debt costs and investment opportunities.

Based on the reviewed literature, the following hypothesis is formulated:

H8: Debt-to-Equity ratio (DER) has a negative and statistically significant effect on R&D investment

Based on the above theoretical analysis, this paper constructs the corresponding conceptual model of the present study (see **Figure 1**).

This conceptual model is designed specifically for Saudi Firms under Uncertainty. It illustrates how key Financial Determinants influence R&D investment.

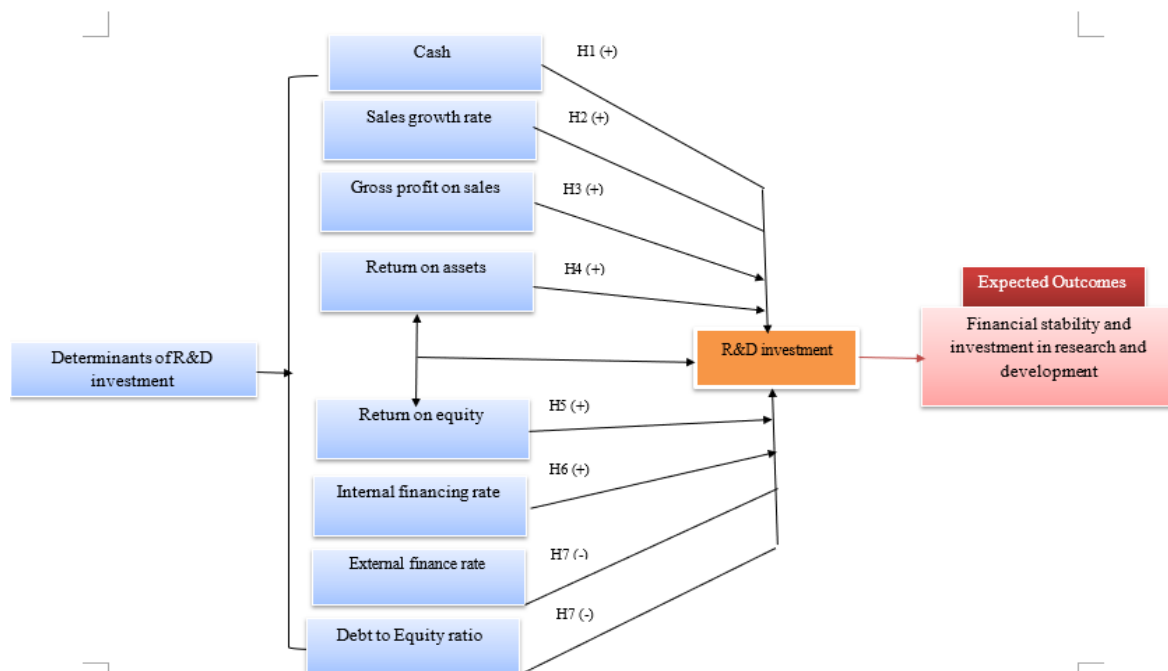


Figure 1. Conceptual Model for Determinants of R&D Investment in Saudi Firms. Source: Author's

DATA AND METHODOLOGY

Data

We employed both primary data in this study. We adopted the Purposive Sampling Technique, which relies on the researchers' judgment in selecting sources most capable of providing information relevant to the objectives of the study (Zaman et al., 2025).

Based on the leading Saudi industrial companies listed on the Saudi Exchange (Tadawul), approximately 71.4% of the firms listed on the Saudi Exchange (Tadawul) were considered. Out of 42 listed firms, twelve were excluded due to data unavailability and to maintain a balanced panel structure. We selected the top thirty firms due to their strategic engagement in R&D and the sector's critical role in the national economy. Consequently, the final dataset comprises 30 firms.

Annual financial data spanning 2007–2020 were collected to examine the Determinants of R&D Investment under Uncertainty. Fourteen years of financial statements from the sampled firms were used to construct a balanced panel. In total, 420 firm-year observations were included in the secondary dataset.

The empirical analysis was conducted using STATA17 software, and the data used in this study were obtained from secondary sources, primarily from the official websites and published reports of the selected firms. A comprehensive summary of all variables and their measurement is presented in **Table 1**.

Table 1. Description of variables

Variable type	Variable name	Symbol	Proxy/Measurement	Expected effect	Sources
Dependent variables	R&D investment	R&D	The research and development expenditures are divided by total assets.	_____	(J. Wang et al., 2025)
	Cash	Cash	Cash in Hand + Balance with Central Bank + Balance with other Commercial Banks & Financial Institutions.	Positive	(Ashik-Uz-Zaman et al., 2025)
Independent variables	Sales growth rate	SGR	The sales growth rate (SGR) is calculated as the percentage change in sales between the current period and the previous period.	Positive	Annual Report (Income Statement)
	Gross profit on sales	GPS	The gross profit margin measures the proportion of revenue remaining after deducting the cost of goods sold, expressed as a percentage of total revenue.	Positive	Annual Report (Income Statement)
	Return on assets	ROA	Profit after tax -to-Total Assets	Positive	(Ashik-Uz-Zaman et al., 2025),(Istaitieh et al., 2024)
	Return on equity	ROE	Profit after tax -to-Total Equity	Positive	(Bhatia & Kumar, 2025; Istaitieh et al., 2024)
	Internal financing rate	TETL	Measures the proportion of total equity relative to total liabilities, indicating the extent to which a firm relies on internal financing.	Positive	Annual Report (Balance Sheet)
	External finance rate	TDTL	Measures the proportion of total debt relative to total liabilities, indicating the extent to which a firm's obligations are composed of debt financing.	Negative	Annual Report (Balance Sheet)
	Debt to Equity ratio	DER	Measures the proportion of total debt relative to shareholders' equity, indicating the degree of financial leverage and the firm's reliance on external financing.	Negative	Annual Report (Balance Sheet)

Method

This study uses a quantitative research approach, employing multiple regression to examine the relationship between investment in research and development and the financial determinants of companies. The study employed descriptive statistics to summarize the characteristics of the variables under investigation, including

measures such as the mean, standard deviation, minimum, and maximum values. These statistics provide an overview of the distribution and central tendencies of the study variables. In addition, a correlation matrix was used to examine the strength and direction of the relationships among the variables included in the model. This analysis helps identify potential associations between the dependent and independent variables before conducting regression analysis. Analysis of variance (ANOVA) was further applied to assess two-factor ANOVA, evaluating how two major economic shocks, the 2008 Financial Crisis and the COVID-19 pandemic, affected firms' mean R&D investment over the period 2007–2020. Likewise, simple linear regressions were implemented to provide preliminary evidence on the direction and magnitude of associations between R&D investment and selected explanatory variables.

To ensure robust causal inference and to address endogeneity concerns, the empirical analysis ultimately relied on a one-step system GMM dynamic panel estimator. This approach accounts for firm-specific unobserved heterogeneity and potential autocorrelation arising from the inclusion of lagged dependent variables. By incorporating additional moment conditions, the system GMM framework provides a more efficient estimation strategy under valid assumptions and enables the assessment of both short- and long-run effects of R&D investment and Financial Determinants (Arellano & Bond, 1991).

Econometric Model

Based on the preceding theoretical analysis, this study develops a model specifically tailored to Saudi firms operating under conditions of uncertainty. The model identifies the relationships among key firm-level financial determinants and highlights how these factors jointly influence the level of investment in research and development (R&D) amid economic uncertainty. In doing so, it contributes to fostering a resilient framework that supports the continuity of R&D activities and safeguards firms' financial stability, while providing a structured foundation for empirical investigation in such challenging contexts.

The operational and empirical specification of the model can be summarized as follows:

Investment in research and development = $f(\text{specific determinants}) \dots (1)$

The model is constructed by extending the variables included in Equation (1) to examine the determinants of investment in research and development (R&D) among Saudi firms. According to the model, the following firm-specific factors are considered:

$$R\&D_{it} = \beta_0 + \beta_1 \text{Cash}_{it} + \beta_2 \text{SGR}_{it} + \beta_3 \text{GPS}_{it} + \beta_4 \text{ROA}_{it} + \beta_5 \text{ROE}_{it} + \beta_6 \text{IFR}_{it} + \beta_7 \text{EFR}_{it} + \beta_8 \text{DER}_{it} + \epsilon_{it} \dots (2)$$

Where:

- R&D_{it} is the R&D investment ratio for firm i at time t
- Cash = Cash
- SGR=Sales growth rate
- GPS=Gross profit on sales
- ROA=Return on assets
- ROE=Return on equity
- IFR=Internal financing rate
- EFR=External finance rate
- DER=Debt to Equity ratio
- ϵ_{it} = Error term

ANALYSIS AND FINDINGS

Descriptive Analysis

Before starting the quantitative estimation, it is necessary to understand the nature of the data through descriptive analysis, which provides an initial overview of the distribution of variables, their homogeneity, and the presence of any outliers or missing values that may affect the results.

Table 2. Descriptive Statistics Of Key Variables

2007-2020	Mean	Median	Max	Min	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability
CASH	0.61	0.45	3.00	0.01	0.60	1.74	6.77	165.08	0.000
DEBT-TO-EQUITY RATIO	0.59	0.50	4.00	0.00	0.59	2.33	12.03	645.15	0.000
EXTERNAL_FINANCE_RATE	0.44	0.50	1.20	0.00	0.27	-0.05	2.09	5.19	0.074
GROSS_PROFIT_ON_SALES	0.24	0.20	3.00	0.00	0.36	6.34	49.09	14278.84	0.000
INTERNAL_FINANCING_RAE	1.81	1.10	12.00	0.14	2.03	2.61	10.48	519.76	0.000
R_D_INVESTMENT	0.74	0.40	5.00	0.01	0.92	2.18	7.98	274.22	0.000
RETURN_ON_ASSETS	0.41	0.20	4.00	0.00	0.78	3.53	14.93	1191.49	0.000
RETURN_ON_EQUITY	0.40	0.20	4.00	0.00	0.78	3.54	15.04	1218.74	0.000
SALES_GROWTH_RATE	0.26	0.15	4.00	0.00	0.44	5.24	39.97	9230.35	0.000

Notes: This table reports the summary statistics — Mean, Median, Maximum (Max), Minimum (Min), Standard Deviation (Std. Dev.), Skewness, Kurtosis, Jarque-Bera test statistic, and Probability values. Source: Author's calculations using STATA17

Table 2 presents financial ratios and performance indicators for the years 2007–2020. Each column summarizes multiple statistical measures for a given metric, while each row corresponds to a distinct financial variable. Likewise, descriptive data for key macroeconomic variables are reported for the entire period

In particular, the substantial Jarque-Bera values and low p-values (below 0.05) indicate that the data are not normally distributed. This evidence suggests that both the COVID-19 pandemic and the 2008 Global Financial Crisis significantly affected the trends of key macroeconomic variables. Skewness measures asymmetry, while kurtosis reflects the presence of heavy tails or outliers. Examination of the values reveals significant skewness and kurtosis in several variables, confirming deviations from normality. Similarly, the low probabilities from the Jarque-Bera test reinforce that the data are non-normal and not randomly distributed.

Time Series Analysis of Financial Metrics

The following time series plots provide a visual analysis of various financial metrics over the years, **Figure 2 - 4**. Each metric is plotted against time, from 2007 - 2020, to highlight trends, patterns, and fluctuations. This analysis helps in understanding the financial behaviors and conditions that could impact the R&D investment these metrics represent.

Figure 2 During the Global Financial Crisis (GFC), many firms increased their R&D spending to maintain competitiveness, while others reduced investments, especially in 2009, as financial pressures forced cost-cutting. A similar pattern emerged during the COVID-19 pandemic, where numerous firms scaled back R&D to protect short-term liquidity, though some continued investing to adapt to rapidly changing market conditions. These fluctuations highlight the complex link between R&D activity and periods of heightened uncertainty.

Statistical analysis shows that R&D expenditures are strongly correlated with financial determinants indicators during the GFC, demonstrating that firms with stronger financial positions were more responsive and more likely to sustain or expand R&D. In contrast, during COVID-19, R&D showed weaker responsiveness, indicating that firms' financial conditions played a decisive role in their ability to manage uncertainty. Overall, the findings underscore that financial determinants significantly shape R&D investment decisions during crises, influencing whether firms innovate or retrench. The results are consistent with the study (Lai et al. 2015) and (Wu et al., 2016).

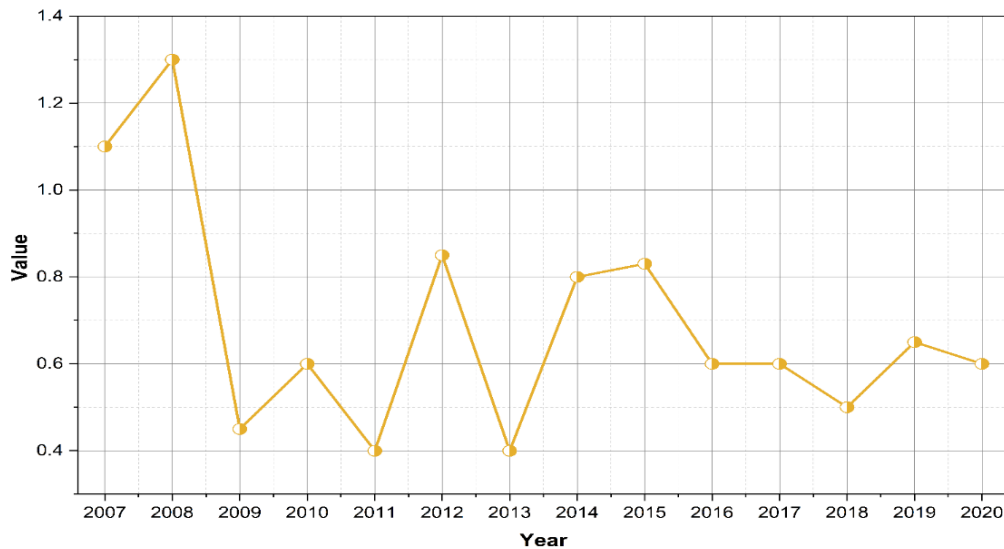


Figure 2. Investing in Research and Development

Figure 3 Sales growth is crucial for determining firms' ability to maintain investment in research and development (R&D) during economic crises. An increase in sales growth not only indicates market expansion and operational resilience but also generates the required cash flow to direct resources toward R&D activities, thus mitigating the risk of investment contraction in times of uncertainty. The results are consistent with the study by Brzozowski (2008). Also closely linked to this is the gross profit on sales, which indicates a company's operational efficiency and its capacity to sustain profitability in the face of challenging circumstances. Companies whose gross profit margins are more robust are in a better position to fund R&D internally, as their higher retained earnings enable them to reinvest in innovation while avoiding excessive dependence on external financing. The results are consistent with the study (Balkin & Gomez-Mejia, 1984).

In the same vein, return on assets (ROA) sheds light on how well a company makes use of its resources to produce earnings. This is especially vital in times of crisis, when it is crucial to allocate assets efficiently. A greater ROA indicates not just improved operational performance but also raises the chances of maintaining or even augmenting R&D investment in times of financial constraint. The results are consistent with the study by Safitri et al.(2020).

Complementing this measure is return on equity (ROE), which highlights the value created for shareholders. In periods of crisis, firms with higher ROE are more likely to maintain investor confidence and attract capital, both of which are crucial for supporting long-term R&D commitments. The results are consistent with the study by Jakpar et al.(2018).

Taken together, sales growth, gross profit on sales, ROA, and ROE provide a comprehensive framework for understanding how firms' profitability and financial performance directly influence their ability to invest in R&D during times of crisis, underscoring the interdependence between financial strength and innovation capacity.

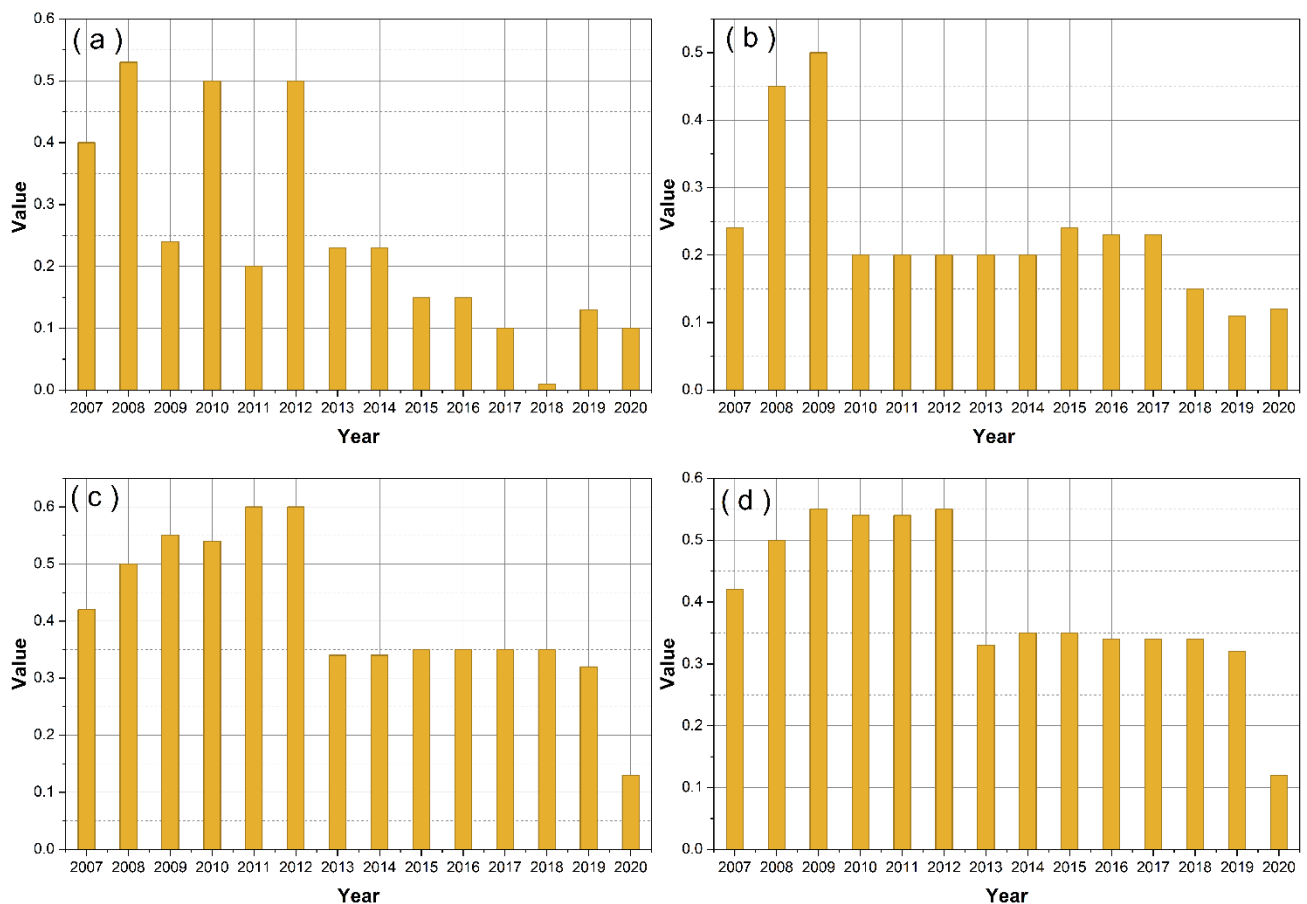


Figure 3. Profitability and Performance Indicators: (a) Sales Growth Rate , (b) Gross Profit on Sales , (c) Return on Assets (ROA) , (d) Return on Equity (ROE).

The financial strength and resource allocation of a company heavily influence its ability to maintain investment in research and development (R&D) during crises. As companies with more robust cash reserves are better able to maintain their R&D investments in the face of disruptions, average cash is among the most crucial factors. Daily operations are supported by adequate liquidity, which also guarantees that companies can finance innovation activities seamlessly. On the other hand, a lack of adequate cash flow in times of crisis (e.g., the COVID-19 pandemic) can elevate the risk of insolvency for companies. This situation may compel them to reduce their long-term investments, such as those in R&D, which can weaken their future competitiveness. The results are consistent with the study by He and Wintoki (2016).

Another closely related concept is the internal financing rate, which indicates how much a company depends on retained earnings to finance its operations and innovative efforts.

In uncertain times, internal financing is especially beneficial because it enables companies to fund R&D without incurring external borrowing costs or facing doubts from investors. As a result, firms that create robust internal funding are more likely to maintain innovative endeavors in times of crisis. When internal resources fall short, companies frequently resort to external financing rates, depending on debt or equity markets for investment funding. The results are consistent with the study by Himmelberg and Petersen (1994).

External funding can help sustain R&D, particularly when governments and financial institutions offer advantageous credit terms in times of crisis. Nonetheless, reliance on external sources can make companies vulnerable to repayment pressures and investor risk aversion, which may impede innovation if not properly managed. The results are consistent with the study by Czarnitzki and Hottenrott (2011).

The debt-to-equity ratio is a crucial indicator of leverage and financial stability, impacting a company's capacity to obtain funding for R&D. Moderate leverage can be advantageous, as it enforces financial discipline on management and may boost creditors' confidence, thus supporting investment in innovation. However,

depending too much on debt in times of crisis increases the likelihood of default and can restrict long-term funding for R&D. When combined, these financing variables cash holdings, internal and external financing, and leverage create a comprehensive framework for understanding how financial structures influence firms' ability to invest in R&D during crises, emphasizing the necessity of balanced financial strategies to protect innovation capacity. The results are consistent with the study by Rachma and Syachrudin (2017).

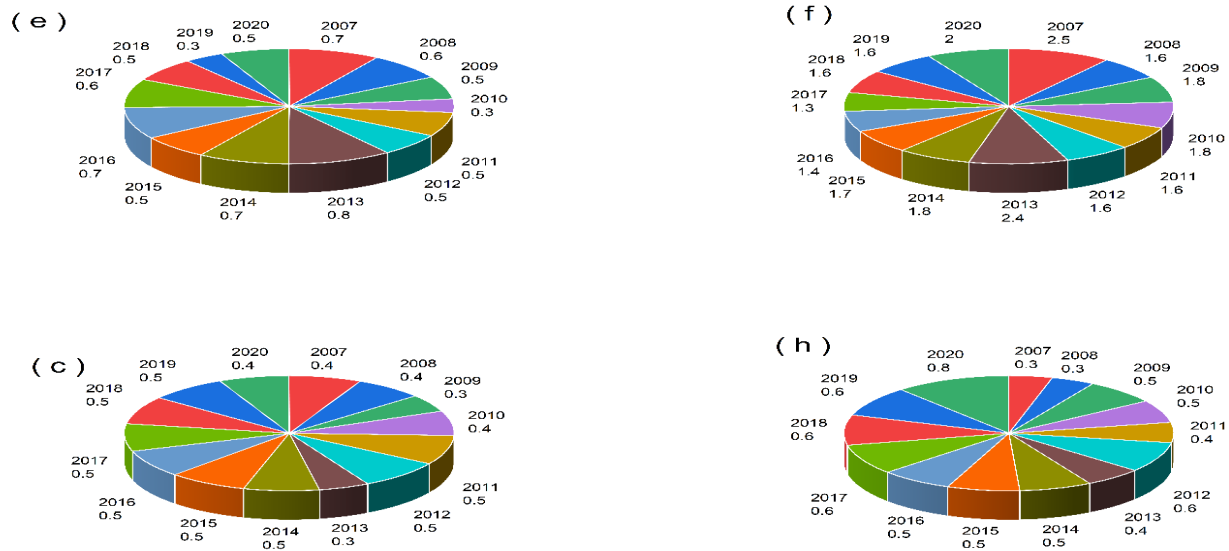


Figure 4. Financing and Capital Structure Indicators: (e) Cash , (f) Internal Financing Rate , (g) External Financing Rate, (h) Debt-to-Equity Ratio.

Financial Metrics Correlation Analysis

The correlation matrix is used to understand the linear relationships between variables and to determine if there is a multicollinearity problem that might affect model estimates. The matrix was calculated using the pairwise correlation method.

Table 3 presents the pairwise correlation coefficients among the study variables, providing initial insights into the relationships between financial determinants and research and development (R&D) investment under conditions of uncertainty. Overall, most correlation coefficients remain below the conventional multicollinearity threshold of 0.80, suggesting that severe multicollinearity is unlikely to affect the subsequent regression estimates (Gujarati, 2021).

Table 3. Correlation matrix between variables.

Metric	CASH	DER	EFR	GPS	IFR	R&D	ROA	ROE	SGR
CASH	1	-0.42	-0.11	0.025	0.304	-0.072	-0.263	-0.257	-0.108
DER	-0.42	1	0.299	-0.371	-0.512	-0.166	-0.482	-0.494	-0.56
EFR	-0.11	0.299	1	-0.376	-0.633	0.157	0.107	0.102	-0.224
GPS	0.025	-0.371	-0.376	1	-0.037	0.248	0.473	0.491	0.426
IFR	0.304	-0.512	-0.633	-0.037	1	0.005	-0.147	-0.14	0.228
R&D	-0.072	-0.166	0.157	0.248	0.005	1	0.04	0.068	0.554
ROA	-0.263	-0.482	0.107	0.473	-0.147	0.04	1	0.998	0.646
ROE	-0.257	-0.494	0.102	0.491	-0.14	0.068	0.998	1	0.67
SGR	-0.108	-0.56	-0.224	0.426	0.228	0.554	0.646	0.67	1

Note: The table reports correlation coefficients between financial metrics for the sample of 30 Saudi industrial companies from 2007 to 2020. Values range from -1 to 1, indicating the strength and direction of linear relationships between variables. Positive coefficients denote a direct relationship, while negative coefficients denote an inverse relationship. Correlations close to ±1 indicate strong associations, whereas values near 0 suggest weak or no linear relationship. Source: Author's calculations using STATA17

Analysis of Variance (ANOVA) for Main Effects

Table 4 reports the results of a two-factor ANOVA assessing the effects of two major economic shocks, the 2008 Financial Crisis and the COVID-19 pandemic, on firms' average R&D investment over the period 2007–2020. The findings reveal a statistically significant main effect of the Financial Crisis ($F = 6.96$; $p = 0.0216$), suggesting that firms' R&D investment levels differed significantly between crisis periods and normal economic conditions. This result indicates that the financial crisis had a measurable impact on firms' innovation investment behavior, potentially reflecting the role of financial constraints in shaping R&D decisions during periods of economic stress.

In contrast, the COVID-19 crisis exhibits an insignificant effect ($F = 0.04$; $p = 0.8374$), implying that the pandemic did not generate a statistically detectable shift in mean R&D investment during the sample period. This limited influence may reflect that firms perceived innovation as essential for resilience and post-crisis recovery, thereby maintaining or even stabilizing R&D spending despite operational disruptions caused by the pandemic.

Collectively, the results indicate that macroeconomic shocks do not uniformly influence R&D behavior; only shocks that fundamentally disrupt financial conditions appear to generate systematic reductions in innovation expenditure.

Table 4. Analysis of Variance for mean_ R&D investment.

Source	SS	Df	MS	F-Ratio	P-Value
MAIN EFFECTS					
A: Financial Crisis	0.337032	1	0.337032	6.96	0.0216
B: COVID-19 Crisis	0.00213011	1	0.002130	0.04	0.8374
RESIDUAL	0.58104	12	0.04842		
TOTAL (CORRECTED)	0.918291	14			

Note: This table reports a two-factor ANOVA examining the effects of the 2008 Financial Crisis (A) and the COVID-19 Crisis (B) on mean R&D investment (2007–2020). SS = Sum of Squares, Df = Degrees of Freedom, MS = Mean Square, F = F-Ratio, and P = P-Value.

Simple Linear Regression Model

Table 5: The regression analysis indicates a weak to moderate positive association between Economic Policy Uncertainty (EPU) and R&D investment, as evidenced by a correlation coefficient of 0.364. While the direction of the relationship suggests that firms may increase R&D expenditure in response to rising uncertainty, the effect is not strong, reaffirming that the relationship is limited in scope. The model's explanatory power is relatively low, with an R-squared of 13.22% and an adjusted R-squared of 6.55%.

This indicates that EPU alone accounts for only a small fraction of the variation in R&D investment, highlighting the influence of other financial and operational factors, such as liquidity, leverage, profitability, firm size, and sector-specific technology intensity. This finding aligns with the broader R&D literature, which suggests that uncertainty impacts innovation through multiple interacting channels rather than a single direct mechanism. The regression diagnostics further support the reliability of the model. The Durbin–Watson statistic (1.786, $p = 0.318$) and residual autocorrelation (-0.031) indicate no significant serial correlation, suggesting that the error structure is well-behaved. Prediction error metrics, including the standard error of estimate (0.248) and mean absolute error (0.208), show moderate predictive accuracy, consistent with the limited explanatory power of EPU. From a scientific perspective, the positive coefficient implies that firms may strategically increase R&D under uncertainty, reflecting long-term innovation behavior. However, the magnitude of the effect (0.22) is moderate and statistically insignificant, confirming that EPU is not a decisive determinant of R&D investment. During major crises, such as the Global Financial Crisis or the COVID-19 pandemic, some firms intensify innovation to secure future growth, while others reduce R&D to conserve liquidity, weakening the overall statistical relationship. In conclusion, EPU has a directional but limited effect on R&D investment. Corporate innovation decisions are influenced by a broader set of financial, operational, and contextual factors, and uncertainty alone cannot fully explain R&D behavior.

Table 5. Regression Model Parameters Coefficients

Statistic	Value
Correlation Coefficient	0.363611
R-squared	13.2213%
R-squared (adjusted for d.f.)	6.54602%
Standard Error of Est.	0.247585
Mean Absolute Error	0.208478
Durbin-Watson Statistic	1.78558
Durbin-Watson P-Value	0.3177
Lag 1 Residual Autocorrelation	-0.031134

Note: Correlation Coefficient shows the relationship strength and direction; R² and Adjusted R² indicate variance explained; S.E. and M.A.E. assess model accuracy; Durbin-Watson and Lag 1 Residual Autocorrelation test for residual autocorrelation.

Dynamic Panel Estimation

Table 6 presents the one-step System-GMM dynamic panel estimation used to examine how firms' R&D investment responds to financial and performance indicators before and after the 2008 financial crisis. The model includes the R&D term and a set of explanatory variables and is estimated separately for the crisis year (2008) and the post-crisis period (2009–2011).

The results indicate that R&D activity was highly persistent during the crisis (coefficient = 1.808, $p < 0.05$) but became far less so afterward (0.237, $p < 0.10$), suggesting that innovation decisions were strongly locked in during the downturn but more flexible in the recovery.

Cash had a large and significantly negative association with R&D in 2008 (-5.752 , $p < 0.01$), implying that firms with high liquidity tended to withhold R&D spending—likely reflecting precautionary cash-hoarding behavior—while this relationship vanished in later years. In contrast, profitability measures shifted in importance: gross profit on sales was a strong positive determinant of R&D during the crisis (3.280, $p < 0.01$) but became insignificant afterward, whereas ROA showed the opposite pattern, rising from a modest crisis effect (1.390, $p < 0.01$) to a much stronger post-crisis impact (5.706, $p < 0.01$), indicating that profitable firms expanded R&D once conditions stabilized. ROE, omitted in the crisis regression, turned significantly negative after 2009, suggesting that high equity returns did not necessarily translate into innovation spending. Leverage (debt-to-equity ratio) was positively related to R&D in 2008 (1.718, $p < 0.05$) but not thereafter, implying that debt financing may have temporarily supported R&D during financial stress.

Coefficient-difference tests confirm that these structural shifts, particularly in R&D persistence, cash holdings, profitability, and leverage, are statistically significant between the two periods. Diagnostic statistics (Arellano-Bond and Hansen tests) support model validity and absence of serial correlation, while Wald tests confirm joint significance. Overall, the findings provide evidence consistent with a causal interpretation that the determinants of R&D investment changed markedly across the crisis cycle: firms curtailed innovation when liquidity pressures intensified, but profitability became the dominant driver in the recovery phase.

Table 6. GMM system one-step Dynamic panel-data estimation

variable's	Finance Crisis (2008) N=30		Post Crisis(2009-2011) N=30		Coefficients Different Test		
	Coefficient	Std. err.	Coefficient	Std. err.	diff	z-diff	P-value
R&D							
R&D ₋₁	1.808**	0.734	0.237*	0.113	1.57	2.115	0.034
cash	(-5.752)**	1.765	0.381	0.363	-6.13	-3.404	0.001
Sales growth rate	0.530	0.723	(-0.101)*	0.047	-0.48	-0.592	0.054
Gross profit on sales	3.280**	0.570	(-0.219)	0.621	3.50	4.151	0.000
ROA	1.390**	0.392	5.706**	1.411	-4.32	-2.947	0.003
ROE	0.000	(omitted)	(-5.688)**	1.368	-----	-----	0.000
Internal financing rate	0.530	0.392	(-0.219)	1.414	-4.35	-2.967	0.001
External finance rate	0.654	0.333	0.382	1.411	-0.45	2.234	0.023
Debt to equity ratio	1.718**	0.552	0.128	0.136	1.59	2.797	0.005
AB test for AR(1) (p-values)		0.205		0.091			
AB test for AR(2) (p-values)		0.456		0.107			
Sargan test (p-values)		---		0.699			
Hansen test (p-values)		---		0.345			
Wald Test		Constraint ROE dropped chi2(5) = 247.76 Prob > chi2 = 0.000		chi2(6) = 369.7 Prob > chi2 = 0.000			

Note: Comparison of R&D and financial metrics across the 2008 Financial Crisis (N = 30) and the post-crisis period (2009–2011, N = 30). Coefficients and standard errors are reported for each variable, with the difference, z-statistic, and P-value indicating statistically significant changes. Significance levels: *P < 0.05, **P < 0.01. AB tests for AR(1) and AR(2) assess autocorrelation; Sargan and Hansen tests evaluate instrument validity. Wald tests indicate overall model significance, with ROE omitted due to multicollinearity.

Table 7 reports one-step System-GMM estimates of how firm financial and performance indicators relate to R&D investment during the COVID-19 crisis (2019–2020, N=30) versus the pre-COVID period (2017–2018, N=30), and the coefficient-difference tests show several statistically meaningful structural shifts. Most strikingly, the lagged R&D term changes sign and magnitude: it is negative during COVID (–0.473, p<0.10) but positive pre-COVID (0.416, p<0.10), and the difference is highly significant (diff = –0.89, z = –4.331, p = 0.000), indicating that persistence in R&D behavior that existed before the pandemic disappeared (or reversed) during the shock year. Average cash holdings are strongly negatively associated with R&D in the COVID period (coefficient = –0.766, p<0.01) but not before (0.231, n.s.), with a significant change across periods (diff p = 0.000), which is consistent with precautionary cash-hoarding or liquidity conservation reducing innovation spending during the pandemic. Sales growth is positively related to R&D in both samples (COVID: 3.627, p<0.01; pre-COVID: 2.266, p<0.10), and the difference is only marginal (diff p ≈ 0.093), implying that firms with stronger sales momentum continued to invest in R&D across periods. Gross profit on sales shows a large positive and significant association with R&D during COVID (6.258, p<0.01), while it is omitted or not significant pre-COVID, pointing to margin-rich firms being better able to sustain innovation under stress. Profitability measures shift roles: ROA is a much stronger positive predictor before COVID (5.733, p<0.01) than during COVID (0.763, n.s.), with the change significant (diff p = 0.015), whereas ROE is strongly negative pre-COVID (–5.803, p<0.01) but not significant in the COVID sample (diff p = 0.010); these differences suggest that which profitability metric correlates with R&D altered between normal and crisis times (possibly reflecting changes in accounting performance, risk preferences, or financing constraints). Leverage (debt-to-equity) is positively associated with R&D during COVID (0.188, p<0.10) but not pre-COVID (0.026, n.s.), and the difference is marginally significant (diff p ≈ 0.054), which may indicate that some firms used debt financing to support R&D during the pandemic.

Diagnostic tests (Arellano–Bond AR tests, Sargan/Hansen) do not flag serious instrument problems, and Wald tests show joint significance, lending credibility to the estimates under the usual GMM assumptions.

Table 7. GMM system one-step Dynamic panel-data estimation

variable's	COVID-19 Crisis (2019-2020) N=30		Pre COVID-19 Crisis(2017-2018) N=30		Coefficients Different Test		
	Coefficient	Std. err.	Coefficient	Std. err.	diff	z-diff	p-value
R&D							
R&D ₋₁	-0.473*	0.184	0.416*	0.091	-0.89	-4.331	0.000
cash	-0.766**	0.151	0.231	0.224	-1.00	-3.691	0.000
Sales growth rate	3.627**	0.894	2.266*	0.937	1.36	1.051	0.053
Gross profit on sales	6.258**	0.815	0.000	(omitted)	-----	-----	0.000
ROA	0.763	0.668	5.733**	1.936	-0.89	-4.331	0.015
ROE	-0.538	0.722	-5.803**	1.905	-1.00	-3.691	0.010
Internal financing rate	0.744	0.833	2.267*	1.956	1.22	-2.331	0.000
External finance rate	0.356	0.567	2.145*	1.865	1.32	-3.387	0.034
Debt to equity ratio	0.188*	0.076	0.026	0.036	1.36	1.051	0.054
AB test for AR(1) (p-values)	0.126		0.211				
AB test for AR(2) (p-values)	---		0.464				
Sargan test (p-values)	0.619		---				
Hansen test (p-values)	0.538		---				
Wald Test	chi2(6) = 93.4 Prob > chi2 = 0.000		chi2(5) = 15770.35 Prob > chi2 = 0.000				

Note: Comparison of R&D and financial metrics during the COVID-19 crisis (2019–2020, N = 30) and pre-crisis period (2017–2018, N = 30). Coefficients, standard errors, differences, z-statistics, and P-values indicate significant changes. Significance levels: *P < 0.05, **P < 0.01. AB tests for AR(1) and AR(2) assess autocorrelation; Sargan and Hansen tests evaluate instrument validity. Wald tests show overall model significance, with some variables omitted due to multicollinearity.

The Results of the Hypothesis Tests

Table 8 presents a summary of the comparison between the expected and actual signals of the independent variables affecting R&D. The results of the hypothesis tests and the statistical significance levels are also shown in the table.

Table 8. Summary of the comparison test result with expectation

Independent variable	Expected result	Actual result	Significant level	Hypothesis test
Cash	positive	Negative	Significant at 1%	Reject
Sales growth rate	positive	positive	Significant at 5% and 10%	Failed to reject
Gross profit on sales	positive	positive	Significant at 1%	Failed to reject
Return on assets	positive	positive	Significant at 1%	Failed to reject
Return on equity	positive	Negative	Significant at 1%	Reject
Internal financing rate	positive	positive	Significant at 1%	Failed to reject
External finance rate	Negative	positive	Significant at 1%	Reject
Debt to Equity ratio	Negative	positive	Significant at 1%	Reject

Source: Author Inferences drawn from the regression analysis

CONCLUSION

We investigate how key financial indicators are associated with firms' R&D activity across different crisis periods, including the 2008 Financial Crisis and the COVID-19 pandemic. Our empirical findings indicate that firms' liquidity, profitability, and capital structure exhibit significant associations with R&D investment, and the effects vary across crisis and non-crisis periods.

In all model specifications, sales growth and profitability measures (gross profit, ROA) consistently emerge as significant determinants of R&D intensity, whereas the role of cash holdings and leverage is highly context-dependent, being particularly important during crisis periods. Interestingly, we find that firms with stronger

internal financing and margin-rich operations are better able to sustain or expand R&D during financial shocks, whereas excessive cash holdings or high leverage can restrain innovation under stress.

All in all, our study contributes to the literature by highlighting that the determinants of R&D investment are dynamic and contingent on both firm-specific financial health and broader macroeconomic conditions. Importantly, the explanatory power of individual financial indicators shifts across crises, which suggests that firm innovation behavior responds differently to liquidity pressures, profitability changes, and debt constraints depending on the economic context. A potential avenue for future research could involve examining a larger sample of firms across multiple countries and crises, allowing researchers to explore how heterogeneous financial structures shape R&D investment under varying economic and policy uncertainties.

Direction for further research

In order to account for firm-specific budgetary restrictions, this study uses purposive sampling approaches to investigate the factors that influence research and development (R&D) investment in the Kingdom of Saudi Arabia. However, the use of cross-sectional data raises the possibility of aggregation bias in the study. One of the study's shortcomings is that the robustness of its conclusions could be strengthened by using various metrics of financial restrictions. Future studies should include macroeconomic variables in the analysis to further our comprehension of the dynamics driving R&D spending.

Moreover, the findings related to cash holdings, return on equity, external financing, and the debt-to-equity ratio are inconsistent with theoretical expectations, suggesting that these factors warrant further investigation in future studies. To better assess their impact on R&D investment, subsequent research could integrate these variables into the empirical model.

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