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Article

The Impact of R&D Innovation Success on the Relationship between R&D Investment and Financial Leverage

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Abstract: This paper explores the interrelationship between R&D investment, financial leverage, and a firm's R&D innovation success. Using a sample of UK and EU firms, we predict that changes in one-year-ahead R&D investment are negatively associated with changes in financial leverage in the current period. Crucially, we also predict that this negative association is positively moderated by the extent to which firms are successful in generating commercially viable and technically feasible innovations from their R&D work. We use insights from International Accounting Standard (IAS) 38: *Intangible Assets* to measure R&D innovation success. Our empirical findings offer strong support for each of our theoretical predictions. Consequently, we contribute to the extant literature by demonstrating that R&D innovation success influences how firms finance their subsequent investments in R&D. Our work also shows that accounting disclosures have the potential to play an important role in open innovation networks.

Keywords: R&D innovation success; R&D investment; financial leverage; R&D success; capitalization of R&D; commercially viable; technically feasible; open innovation networks

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1. Introduction

Investment in Research and Development (R&D) is crucial to the long-term success of firms [1] and nations [2] and has increased dramatically over time [3]. In the contemporary competitive landscape, R&D investments play a crucial role in a firm's innovation strategies [4]. For many firms, successful investment in R&D is necessary to survive and thrive in today's globally competitive environment [1]. Nonetheless, investment in R&D is typically a high-risk proposition with a long-term payoff horizon [5].

This study seeks to extend research on the relationship between R&D investment and financial leverage [6,7]. Drawing on extant theory, we predict a negative relationship between changes in one-period-ahead R&D investment and current-period financial leverage changes. We then argue that success with R&D innovations reduces the risk associated with R&D investment from the perspective of both management and the providers of debt finance. Consequently, we predict that R&D innovation success positively moderates the relationship between investment in R&D and financial leverage.

Our measure of R&D innovation success is drawn from International Accounting Standard (IAS) 38 38: *Intangible Assets* [8]. IAS 38 requires that R&D expenditure is treated as an asset (i.e., capitalized) on a firm's balance sheet when it meets several specific criteria (which we elaborate upon later) to evaluate technical feasibility and commercial viability. The process whereby R&D expenditure is classified as an asset is subject to scrutiny from the firm's financial reporting and internal audit teams and must meet the approval of the firm's board of directors [9], as well as by the firm's external auditor [10]. Consequently, capitalization of R&D expenditure sends a verifiable signal formally attesting to the success of a firm's R&D work [11].

For our empirical work, we compile a sample of UK and EU firms that apply IAS 38 *Intangible Assets*. Using a range of estimation methodologies, we show that current period financial leverage has a negative relationship with one-period-ahead R&D investment. However, we also discover, consistent with our a priori theoretical expectations, that the reported negative relationship is positively moderated by R&D innovation success.

The key contribution of our paper is that we show that the way in which R&D innovation is financed is significantly impacted by R&D innovation success. To date, the literature has not addressed the influence of success in R&D innovation on the ways in which R&D innovation is financed. Consequently, by addressing this gap in the extant literature, our paper offers a unique contribution to research at the interface of open innovation systems [12], capital markets [13], accounting [14], and corporate strategy [15]. We discuss the objectives of our paper—in the context of extant literature in Section 2.

In addition to the novel theoretical focus of our work, a unique aspect of our paper is that we empirically address our research questions by employing a pan-European dataset (drawn from firms listed on the FTSEurofirst 300 index) which includes several EU countries as well as the UK. Our empirical analysis utilizes a range of panel estimation models [16] to control for a range of potential estimation challenges including model misspecification and endogeneity [17,18]. We describe the data and estimation in Section 3.

The results of our paper are presented in Section 4. Our empirical predictions are supported using a range of alternative econometric approaches and the most important of our findings—that R&D innovation success influences the way in which R&D innovation is financed—is clearly demonstrated in Section 4. In Section 5, we highlight six specific contributions of our paper. These contributions highlight the ways in which our study extends extant literature across several research silos. The concluding part of our paper—Section 6—outlines the explicit policy recommendations for decision-makers arising from our work and presents potential avenues for future research on the key issues addressed in this study.

2. Literature Review and Hypotheses

2.1. R&D Investment and Financial Leverage

Prior work points to several reasons why one-period-ahead R&D investment is likely to be negatively related to financial leverage. First, extant research suggests that higher financial leverage may reduce a firm's free cash flow with a consequent reduction in the free cash flow available for investment in subsequent R&D [19]. Second, firms with high levels of R&D tend to have significant proprietary information about their R&D projects which they do not wish to share with outside parties [20]. Consequently, when such firms seek external debt financing for their R&D investments, providers of debt finance may demand to see confidential information about the success of extant R&D investments and the potential success of proposed R&D projects. If the firm wishes to keep this information proprietary, this information asymmetry problem may discourage debt financiers from financing future R&D activities [21]. Third, even when the initial information asymmetry problem is less evident, debt financiers may seek to impose stringent contractual conditions on the R&D investment process via loan covenants [22]. Such conditions may discourage R&D-intensive firms from accepting debt financing. Fourth, the unique and intangible characteristics of R&D-based assets and investments mean that such assets are often not viewed as offering sufficiently reliable collateral (when compared to tangible assets) to facilitate debt financing [23]. Fifth, debt financing typically requires a fixed schedule of regular repayments. However, R&D investments typically generate net cash flows only after a substantial time has elapsed [15]. The net cash flows generated can be uncertain and uneven [24]. Consequently, the long payback period and volatile net cash flows [25] mean that R&D investments are frequently incompatible with the cash flow demands for interest and principal repayments commiserate with debt financing [25].

Following the rationale outlined above, we expect a negative association between one-period-ahead R&D investment and financial leverage in the current period. We are also aware that prior research reveals that many factors can impact the financial leverage choices of firms [26–29]. Consequently, to control for exogenous factors [30], we refine our theoretical prediction further and express our first hypothesis as follows:

Hypothesis 1 (H1). *Changes in one-period-ahead financial leverage are negatively related to changes in financial leverage in the current period.*

2.2. The Moderating Influence of R&D Innovation Success

Our second hypothesis explores the impact of R&D innovation success on the relationship between financial leverage and R&D investment. The measure of R&D that we use in this study emerges from the treatment of R&D expenditure in contemporary financial reporting; consequently, we will first elaborate on this aspect of the R&D landscape.

There are two dominant sets of accounting standards in operation worldwide [31]. On the one hand, US Generally Accepted Accounting Principles (US GAAP) standards are required for financial reporting purposes by US firms [31–34]. The second set of standards is International Financial Reporting Standards (IFRS)/International Accounting Standards (IAS)). IFRS/IAS are the financial reporting standards utilized by firms in over 130 countries worldwide [32,34].

When it comes to the expenditure on R&D, there are substantial differences between IFRS/IAS and US GAAP [35–37]. For expenditure on research at an early stage that is not yet commercially viable, both US GAAP and IFRS mandate that such expenditures should be treated as an expense in the firm's Income Statement (also known as the Profit and Loss statement). However, US GAAP differs significantly from IFRS for research work that has progressed to the development stage. In an analogous manner to early-stage research expenditure, US GAAP also requires all development expenditure to be expensed to the Income Statement [31]. However, IFRS requires firms to capitalize development expenditure in certain circumstances [38]. Capitalizing development expenditure means treating the expenditure as an asset on the firm's balance sheet (also known as the 'statement of financial position). Capitalization is required if the expenditure is undertaken in the development stage of the research project and meets all five of the specific conditions [39] outlined in IAS 38: *Intangible Assets* [8].

The first criterion outlined in IAS 38 [8] is that the project should be technically feasible in that it has merit from a technical perspective [31]. The second criterion specifies that the firm intends to complete the asset with either the intention of selling it or using it. The third criterion is that the firm should have the potential to access the technical and financial resources required to complete the project. The fourth criterion requires the expenditure on the project to be separately identifiable from expenditures on other projects. The fifth and final criterion specifies that the project must be commercially viable in that the asset will generate future economic benefits [15]. When the project has entered the development phase and met each of the five criteria, the relevant expenditure must be capitalized as an asset on the firm's balance sheet [40].

Capitalization of R&D expenditure sends a powerful signal to stakeholders that a firm's R&D program has been successful because it has yielded an asset that meets the five criteria to justify showing it as an asset on the firm's balance sheet [3,40,41]. The firm's board of directors (the audit committee usually handles this process) and the firm's external auditors need to approve capitalization [9,10]. Consequently, in this study, we view capitalization of R&D expenditure under the rules of International Accounting Standard 38: *Intangible Assets* [8] as a legally binding signal of R&D innovation success [3].

Oswald et al. [5] show that UK firms that capitalized development expenditure after the introduction of IFRS in the UK had higher subsequent R&D expenditures than firms that already capitalized development expenditure voluntarily under the applicable UK-specific accounting rules. This finding suggests, inter-alia, that firms that achieve success in their

R&D programs—as manifest in the capitalization of development expenditure under the requirements of IAS 36—build on this success by investing comparatively more in R&D.

Earlier, we argued that loan finance providers are likely to view R&D investment as risky [42]. However, as a firm records success concerning its R&D program, then the risk associated with R&D investment is likely to be reduced from the perspective of debt financiers [3,14]. Consequently, we predict that success with R&D investment will positively moderate the relationship between R&D investment and financial leverage. Our second hypothesis, therefore, is as follows:

Hypothesis 2 (H2). *R&D innovation success positively moderates the relationship between changes in one-period-ahead R&D investment and changes in financial leverage in the current period.*

2.3. Open Innovation Dynamics

An important element of our R&D innovation success measure is that it contributes in a very real way to open innovation dynamics [12]. When firms are successful in their R&D innovation efforts and signal this success via capitalization of R&D expenditures, firms subsequently go to great lengths to communicate the nature of their R&D innovation success via detailed notes in the financial statements [43,44]. In this sense, our measure of R&D innovation success reflects a central characteristic of open innovation dynamics: the sharing of core information between firms [45]. In this sense, the capitalization of R&D can play a key role in terms of fostering inter-firm web-based idea management systems [46].

While some firms are often loath to share their discoveries for commercial and other reasons [47], the mandatory disclosures required by IAS 38: *Intangible Assets* [8] lead to a sharing—albeit sometimes a forced sharing—of key R&D success-related information, which can ultimately drive open innovation dynamics within an industry. By contrast, some firms go beyond the minimum disclosure requirements by releasing very detailed data—on a voluntary basis—in the notes to the financial statements about the nature of their R&D innovation success [41,43].

Furthermore, the cooperation engendered by the disclosures commiserate with the capitalization decision (as required by IAS 38: *Intangible Assets* [8]) can help augment firms' focus on cooperation from a circular economy perspective [48]. This is of paramount importance in light of the macro-economic constraints that can sometimes hamper R&D innovations [49] and, by association, the open innovation dynamics operating within the organizational climates of specific firms and industries [50].

In summary, there are multifarious ways in which R&D capitalization-related disclosures influence open innovation dynamics. The requirements in IAS 38: *Intangible Assets* [8] ensure that information about R&D innovation success is made publicly available and this, in turn, can have long-term beneficent impacts on open innovation dynamics from the perspectives of nurturing long-term ecologically sustainable and commercially viable innovations across firms, industries, societies and nations [51].

3. Materials and Methods

3.1. Estimation Model

Our core estimation model to test hypothesis 1 is presented in Equation (1) below (where i and t subscripts represent firm and time periods respectively):

$$\Delta\text{R\&D INVESTMENT}_{i,t+1} = f(\Delta\text{FINANCIAL LEVERAGE}_{i,t}, \text{CONTROLS}_{i,t}) \quad (1)$$

In Equation (1), we model the change in one-period-ahead R&D investment (ΔR&D INVESTMENT$_{i,t+1}$) as a function of the change in current period financial leverage (ΔFINANCIAL LEVERAGE$_{i,t}$). We utilize a first difference model for two reasons. First, by focusing on how changes in financial leverage impact change in R&D investment, we mitigate the influence of firm-specific factors related to a firm's choice of the level of both R&D investment and financial leverage [52]. Second, the first difference approach automatically controls for unobservable firm-specific and time-specific influences [16].

We use the one-period-ahead measure of R&D investment in Equation (1) as prior work suggests that it takes time for stock market participants to fully take cognizance of the significance of capitalization [2,53]. We expect that debt market participants will also need time to assimilate the capitalization information [4,54]. Consequently, we focus on one-period-ahead changes in the dependent variable. Hypothesis 1, which predicts a negative and significant relationship between changes in one-period-ahead R&D investment and current period financial leverage changes, implies a negative and significant coefficient on the FINANCIAL LEVERAGE construct in Equation (1) above.

To test our second hypothesis, we extend Equation (1) as follows:

$$\Delta \text{R\&D INVESTMENT}_{i,t+1} = f\{(\Delta \text{FINANCIAL LEVERAGE}_{i,t}, [\Delta \text{FINANCIAL LEVERAGE}_{i,t}, \times \text{RD\_SUCCESS}_{i,t}], \text{CONTROLS}_{i,t})\} \quad (2)$$

In Equation (2), we introduce a term to capture the interaction between the change in financial leverage variable and our measure of research and development success for firm i in period t (ΔFINANCIAL LEVERAGE × RD_SUCCESS). Hypothesis 2, which predicts that the influence of financial leverage on R&D investment is positively moderated by R&D innovation success, implies a positive and significant coefficient on the interaction term in Equation (2).

3.2. Variable Measurement

We now elaborate on how we measure the individual components of Equations (1) and (2) in our empirical tests.

ΔR&D INVESTMENT: Our dependent variable is the one-period-ahead (period t + 1) change in firm i's R&D investment scaled by firm i's total assets [53]. As discussed earlier, some firms capitalize development expenditure, so the amount capitalized will not be included in the R&D expense figure. Consequently, we add back the amount of development expenditure capitalized to the R&D expense figure [3]. The resultant figure represents a firm's total expenditure on R&D for a specific fiscal year [35]. We divide the total R&D expenditure (over the fiscal year) by total assets at the fiscal year-end to scale for size effects. We adjust the total assets figure by removing any capitalized R&D from total assets. Relatedly, we also remove any capitalized R&D from the book value of equity. These adjustments reduce the book value of assets and equity [35,55]. After following these steps, we then calculate the dependent variable in Equation (1) is the one-year-ahead change in the natural logarithm of firm i's R&D expenditures scaled by total assets.

ΔFINANCIAL LEVERAGE: We measure financial leverage as total debt divided by the book value of equity (converted for the capitalization of development expenditure as explained above) at the fiscal year-end [5]. The first difference of this measure captures the change in financial leverage for a period.

RD_SUCCESS: Our measure of research and development success takes a value of 1 if the firm capitalized at least some R&D expenditure in the current period and zero otherwise. This metric has an advantage over others applied in the literature (Oswald, 2008; Oswald & Zarowin, 2007 [3]) in that the measure we employ is based on the firm's assessment of success in its R&D endeavors, and this assessment is formally agreed upon by the firm's board of directors and external auditors. As discussed earlier, firms reporting under International Financial Reporting Standards (IFRS) are required to capitalize R&D expenditure when it meets five specific measures of success. Consequently, when a firm capitalizes R&D expenditure, this signals that at least some element of the R&D expenditure is successful [43].

CONTROLS: Extant research [35,36] points to the importance of controlling for earnings variability. We include a control for changes in earnings variability (ΔEARNINGS VARIANCE) measured as the firm's earnings per share variance divided by the end-of-period stock price. This measure is also log-transformed to control for the potential influence of outliers. Extant research also suggests that profitability [36,55] is a nontrivial influence on a firm's investment in R&D. Consequently, we include a measure of the change in the firm's return on assets (ΔFIRM PERFORMANCE) as a control. For this measure, we adjust net income by deducting any capitalized R&D to measure profitability across firms on an equivalent basis. Following prior research [13,56,57], we include a measure to capture the change in a firm's systematic risk (ΔFIRM RISK), defined as the change in the natural log of each firm's beta [58]. Based on prior work [53], we include the annual change in market capitalization to account for firm size (ΔFIRM SIZE) in our empirical estimates. Finally, we control for growth opportunities [59] by including the change in the firm's market-to-book ratio as a control (ΔMARKET TO BOOK) [3].

After incorporating the controls outlined above and introducing β_o and e to represent the regression intercept and error terms, respectively, Equation (1) may be recast in a form suitable for empirical estimation as follows:

$$\Delta \text{R\&D INVESTMENT}_{i,t+1} = \beta_0 + \beta_1\ \Delta\text{LEVERAGE}_{i,t} + \beta_2\ \Delta\text{MARKET TO BOOK}_{i,t} + \beta_3\ \Delta\text{EARNINGS VARIANCE}_{i,t} + \beta_4\ \Delta\text{FIRM SIZE}_{i,t} + \beta_5\ \Delta\text{FIRM PERFORMANCE}_{i,t} + e_{i,t} \quad (3)$$

Our first hypothesis, which predicts that changes in financial leverage have a negative and significant effect on changes in one-period-ahead R&D Investment, implies that β_1 in Equation (3) is negative and significant.

To test our second hypothesis, we include RD_SUCCESS and the interaction term ΔLEVERAGE × RD_SUCCESS in Equation (4) below:

$$\Delta \text{R\&D INVESTMENT}_{i,t+1} = \beta_0 + \beta_1\ \Delta\text{LEVERAGE}_{i,t} + \beta_2\ \text{RD\_SUCCESS} + \beta_3\ [\Delta\text{LEVERAGE}_{i,t} \times \text{RD\_SUCCESS}] + \beta_4\ \Delta\text{MARKET TO BOOK}_{i,t} + \beta_5\ \Delta\text{EEARNINGS VARIANCE}_{i,t} + \beta_6\ \Delta\text{FIRM SIZE}_{i,t} + \beta_7\ \Delta\text{FIRM PERFORMANCE}_{i,t} + e_{i,t} \quad (4)$$

We include RD_SUCCESS as an additional variable to measure the core interaction effect accurately [52]. Our second hypothesis predicts that R&D innovation success positively moderates the relationship between changes in one-period-ahead R&D investment and financial leverage in the current period (i.e., H2 predicts $\beta_3 > 0$ in Equation (4)).

3.3. Data

The European Union mandated firms to apply international accounting standards—including IAS 38: *Intangible Assets* (IASB, 2004), from 2005 onwards. Recall that IAS 38 outlines the criteria for capitalizing R&D expenditure. From a practical perspective, we assume that the requirements of IAS 38 were adhered to in fiscal 2006, and our sample period extends over fiscal years 2006 to 2011. For our empirical tests, our sample comprises data from firms' financial statements included on the FTSEurofirst 300 index as listed on the London Stock Exchange and recorded on the Datastream database. We exclude firms in the customer services and financial sectors because expenditure on R&D is of limited relevance to such firms [36]. After applying the exclusion criteria described above and excluding firms with incomplete datasets, our sample consists of 434 firm-year observations drawn from 78 firms over the sample period. As we utilize a first-difference estimation methodology, we include 356 firm-year observations (i.e., 434 − 78 = 356) in each regression estimate.

4. Results

4.1. Summary Statistics

We present the summary statistics for our sample in Table 1.

These statistics show a decline in the average change in one-period-ahead R&D investment (ΔR&D INVESTMENT$_{t+1}$ = −0.0619) across the sample firms and also a decrease in the average of firms' financial leverage (ΔLeverage = −0.0982). The mean for the R&D innovation success variable (RD_SUCCESS) is 0.2163, revealing that R&D expenditure is capitalized for 21.63% of firm-year observations. This figure is broadly in line with prior research.

Table 1. Summary statistics.

Variable	N	Mean	Std. Dev.
ΔR&D Investment$_{t+1}$	356	−0.0619	0.886575
ΔLeverage	356	−0.09818	7.679235
RD_SUCCESS	356	0.216292	0.412295
ΔMarket-to-book	356	−0.03201	0.865212
ΔEarnings variance	356	−0.00493	3.256309
ΔFirm size	356	121.6631	11548.8
ΔFirm risk	356	0.027465	0.228164
ΔFirm performance	356	−0.00135	0.050459

We show the sample Pearson correlations in Table 2.

Table 2. Correlation matrix.

		1	2	3	4	5	6	7
1	ΔR&D INVESTMENT$_{t+1}$	1						
2	ΔLEVERAGE	−0.0985	1					
3	RD_SUCCESS	−0.0451	0.0906	1				
4	ΔMARKET TO BOOK	−0.0555	0.7981	0.054	1			
5	ΔEARNINGS VARIANCE	0.0154	−0.0042	0.0113	−0.0191	1		
6	ΔFIRM SIZE	0.0202	−0.0635	−0.0389	0.0227	−0.0325	1	
7	ΔFIRM RISK	0.0518	−0.0242	−0.0757	−0.0103	−0.0528	0.0521	1
8	ΔFIRM PERFORMANCE	0.0204	−0.1078	−0.0856	−0.0894	0.4514	0.204	−0.0525

The statistics in Table 2 show that the correlation between one-period-ahead R&D investment and financial leverage is negative (−0.0985). While most of the correlations are less than 0.1, we note a strong correlation between changes in financial leverage and changes in the market-to-book metric. However, for our regression analysis, we note that this correlation does not impact our core results as the condition index for the regression estimates is 2.82. This value is far below the conventionally accepted threshold [15], indicating that multicollinearity is not an issue in our regression estimates [60].

4.2. Estimation Methods

The first step in our estimation is to choose the appropriate estimation method for our cross-sectional time-series (i.e., panel) dataset. Using the approach described in O'Connell (2007 [16]), we find significant variation across firms. Further examination based on the Hausman test [16,18,61,62] suggests that the firm fixed-effects model [63] is most appropriate in the present context. Our sensitivity analysis (Section 4.2) reports results using random-effects and Driscoll–Kraay estimates [64]. Although our empirical framework—with its focus on a leading dependent variable and first difference estimation—mitigates against endogeneity problems [65], we also test for the presence of endogeneity. We find no statistical evidence of endogeneity using a range of alternative procedures [15,16].

4.3. Regression Results

We present the results of our fixed-effects estimates of Equations (3) and (4) in Table 3.

In Column (1) of Table 3, we show the results when we regress our dependent variable (one-period-ahead changes in R&D Investment (ΔR&D INVESTMENT$_{t+1}$) on the control variables only. In Column (2), we include the change in financial leverage (ΔLEVERAGE) and our measure of R&D innovation success (RD_SUCCESS) as additional independent variables. In Column (3), we introduce a term to capture the interaction between ΔLEVERAGE and RD_SUCCESS. We include year-specific dummy variables in each of the three regressions to capture sample variation across time. We also control for heteroscedasticity [61,66].

Table 3. Results of fixed effects (FE) regressions.

Dependent Variable: ΔR&D Investment in Period t + 1			
	(1)	**(2)**	**(3)**
ΔLEVERAGE		−0.015	−0.020
		−6.142 ***	−7.433 ***
RD_SUCCESS		−0.067	−0.068
		−0.299	−0.304
ΔLEVERAGE × RD_SUCCESS			0.009
			5.045 ***
ΔMARKET TO BOOK	−0.060	0.050	0.065
	−1.071	1.785 *	2.316 **
ΔEARNINGS VARIANCE	0.013	0.014	0.014
	0.919	0.981	0.980
ΔFIRM SIZE	−0.000	−0.000	−0.000
	−0.588	−0.658	−0.648
ΔFIRM RISK	0.136	0.126	0.113
	0.470	0.437	0.388
ΔFIRM PERFORMANCE	−0.765	−0.850	−0.851
	−0.367	−0.409	−0.408
Constant	−0.133	−0.129	−0.129
	−1.301	−1.473	−1.476
Year-dummies	Yes	Yes	Yes
Firm-variance	FE	FE	FE
Observations	356	356	356
R-squared	0.020	0.027	0.028
F	25.83 ***	613.7 ***	828.1 ***

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Hypothesis 1 predicts that changes in financial leverage in the current period have a negative and significant effect on one-period-ahead changes in R&D investment. In Column (2) of Table 3, the regression coefficient estimate for financial leverage is negative and significant at the 1% significance level based on a two-tail significance test (i.e., $\beta_{LEVERAGE} = -0.015$; t-statistic = −7.435, $p < 0.01$). This finding offers strong support for hypothesis 1 by demonstrating that future changes in investment in R&D are negatively impacted by current period changes in a firm's financial leverage. This finding—based on a first difference estimation—is consistent with prior work showing a negative association between levels of R&D investment and financial leverage.

Hypothesis 2 predicts that when firms achieve success in their R&D work, the negative impact of financial leverage on one-period-ahead changes in R&D investment is reduced. The results in Column (3) of Table 3 reveal that consistent with our prediction, the interaction between changes in financial leverage and our measure of R&D innovation success is positive and significant at the 1% level (i.e., $\beta_{[LEVERAGE \times RD\_SUCCESS]}) = 0.009$; t-statistic = 5.045, $p < 0.01$).

Several other points concerning the results in Table 3 are worthy of elaboration. First, we note that when the interaction term and the measure of RD success are both included in the same regression (Column 3), the financial leverage measure remains negative and significant at the 1% level (i.e., $\beta_{LEVERAGE} = -0.020$; t-statistic = −7.433, $p < 0.01$). This result reveals that, even for those firms with no R&D innovation success (i.e., when RD_SUCCESS = 0), the influence of financial leverage on one-period-ahead R&D investment is negative and significant. Second, although not central to our hypothesis tests, we note that changes in growth opportunities are negatively and significantly associated with changes in one-period-ahead investment in R&D in Columns (2) and (3) of Table 3. Third, the results across the three columns in Table 3 reveal that none of the other control variables is significant at conventional levels.

4.4. Sensitivity Tests

We now discuss the results of tests designed to assess the robustness of our findings to alternative estimation methodologies. First, as explained earlier, our primary findings are reported using a fixed-effects estimation model as preliminary testing suggests that the fixed effects model is more appropriate in the present context. Our first sensitivity test utilizes random-effects estimation [18,62] to assess how our choice of panel-estimation models influences our findings. The results of this analysis are presented in Table 4.

Table 4. Results of random effects (RE) regressions.

Dependent Variable: ΔR&D Investment in Period t + 1			
	(1)	**(2)**	**(3)**
ΔLEVERAGE		−0.015	−0.025
		−7.081 ***	−11.320 ***
RD_SUCCESS		−0.074	−0.079
		−0.712	−0.767
ΔLEVERAGE × RD_SUCCESS			0.017
			11.825 ***
ΔMARKET TO BOOK	−0.052	0.057	0.083
	−0.971	2.288 **	3.181 ***
ΔEARNINGS VARIANCE	0.007	0.008	0.008
	0.701	0.782	0.776
ΔFIRM SIZE	−0.000	−0.000	−0.000
	−0.665	−0.750	−0.709
ΔFIRM RISK	0.216	0.202	0.198
	0.893	0.823	0.806
ΔFIRM PERFORMANCE	0.113	−0.003	0.021
	0.076	−0.002	0.014
Constant	0.014	0.035	−0.197
	0.302	0.672	−1.891 *
Year-dummies	Yes	Yes	Yes
Firm variance	RE	RE	RE
Observations	356	356	356

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

As before, the dependent variable for all regressions reported in Table 4 is one-period-ahead changes in R&D investment. In Column (2) of Table 4, we report results for tests of Hypothesis 1 using random-effects estimation. These results reveal a negative and significant (at the 1% level) coefficient on the changes in financial leverage term (i.e., $\beta_{LEVERAGE} = -0.015$; t-statistic = −7.081, $p < 0.01$). In Column (3) of Table 4, we show the results using random-effects estimation when we include the interaction term. Once again, we find that the interaction between R&D innovation success and financial leverage is positive and significant at the 1% significance level (i.e., $\beta_{[LEVERAGE \times RD\_SUCCESS]}) = 0.017$; t-statistic = 11.825, $p < 0.01$). As with the fixed effects results, the regression coefficient on financial leverage in Column (3) when the interaction term is included is negative and significant at the 1% level (i.e., $\beta_{LEVERAGE} = -0.025$; t-statistic = −11.320, $p < 0.01$). As with the fixed effects results, the control for growth opportunities is also negative and significant in Columns (2) and (3) of Table 4.

Our second set of sensitivity tests uses Driscoll–Kraay estimation to control for potential first-order autocorrelation and heteroscedasticity [64]. These results are reported in Columns (1) to (3) of Table 5.

We also include firm dummies and year-dummies in the Driscoll–Kraay regressions to control for firm effects. As with the fixed and random effects estimates: the results in Column (2) of Table 5 offer strong support for Hypothesis 1 ($\beta_{LEVERAGE} = -0.015$; t-statistic = −9.079, $p < 0.01$) and Hypothesis 2 (i.e., $\beta_{[LEVERAGE \times RD\_SUCCESS]}) = 0.009$; t-statistic = 13.486, $p < 0.01$).

Table 5. Results of Driscoll–Kraay regressions.

Dependent Variable: ΔR&D Investment in Period t + 1			
	(1)	**(2)**	**(3)**
ΔLeverage		−0.015	−0.020
		−4.679 ***	−9.079 ***
RD_SUCCESS		−0.067	−0.068
		−0.319	−0.319
ΔLeverage × RD_SUCCESS			0.009
			13.486 ***
ΔMarket to book	−0.060	0.050	0.065
	−11.238 ***	1.419	1.927
ΔEarnings variance	0.013	0.014	0.014
	0.854	0.898	0.891
ΔFirm size	−0.000	−0.000	−0.000
	−0.674	−0.792	−0.788
ΔFirm risk	0.136	0.126	0.113
	0.916	0.896	0.810
ΔFirm performance	−0.765	−0.850	−0.851
	−0.402	−0.448	−0.447
Constant	−0.130	−0.024	−0.026
	−1.888	−0.122	−0.133
Year dummies	Yes	Yes	Yes
Firm variance	Firm Dummies	Firm Dummies	Firm Dummies
R-squared	16.0%	16.6%	16.7%
F-statistic	5.796 **	10.15 **	10.08 **
Observations	356	356	356

*** $p < 0.01$, ** $p < 0.05$.

Third, in unreported results, we find continued support for both hypotheses using two-period and three-period ahead changes in R&D investment as an alternate dependent variable. Fourth, in additional analyses, we verify that our core findings are fully robust to including industry dummies for firm-fixed effects, random effects, and Driscoll–Kraay estimates.

5. Discussion

In this paper, we explore the interrelationship between investment in R&D, financial leverage, and a firm's success with its R&D projects. Our theoretical model predicts that changes in one-period-ahead R&D investment are significantly negatively related to financial leverage changes in the current period. However, we also conjecture that when R&D investment is successful, the negative influence of changes in current period financial leverage on firms' one-period-ahead R&D investment is reduced. This prediction arises because R&D innovation success reduces the risks associated with R&D expenditures and, consequently, encourages both executives and loan providers to deploy higher levels of debt financing when financing subsequent R&D investments.

Consistent with our first theoretical prediction, our empirical results (based on a sample of UK and European Union firms) reveal a negative relationship between changes in one-period-ahead R&D investment and financial leverage. However, per our second theoretical prediction, when a firm experiences R&D innovation success, the negative relation between R&D investment and financial leverage is significantly reduced.

Our work makes several innovative contributions to the extant literature. First, by demonstrating that R&D innovation success reduces the negative relationship between R&D investment and financial leverage, our work highlights the importance of taking cognizance of R&D outcomes [41,67,68]. Our findings show that when R&D work is successful, management is comfortable with using more debt to finance one-period-ahead R&D investment. Relatedly, our findings suggest that providers of debt finance are more comfortable with supplying loans for R&D investment when the firm exhibits success with its R&D projects. While our results with respect to the influence of R&D innovation success on R&D financing are intuitively appealing, ours is the first work to offer empirical evidence for this phenomenon. Consequently, our findings offer unique insights from the perspective of understanding how firms finance their investments in *intangible assets* [30].

Second, while prior work has demonstrated a negative relationship between current period R&D investment and financial leverage [69], we extend this work by adopting a first-difference framework and focusing on one-year-ahead R&D investment. Our focus on the relationship between one-year-ahead changes in R&D investment and changes in financial leverage in the current period highlighted the intertemporal nature of the R&D financing decision. By adopting a first-difference framework, our work controls for endogeneity and omitted variables [3,59].

Third, our study is the first (of which we are aware) to utilize the information offered by a firm's decision to capitalize R&D after applying the detailed criteria of IAS 38 *Intangible Assets* [8] as a signal of R&D innovation success. While prior studies have employed several second-order measures of R&D innovation success [35,36], the measure we utilize is a legally binding measure of R&D innovation success. Firms must capitalize development expenditure when the five criteria outlined in IAS 38 are met [31]. This choice must be approved by the board of directors [9] and must meet the strict scrutiny of an external auditor [10]. Consequently, we believe that the signal sent by the capitalization of development expenditure has not received sufficient attention in the literature. To date, literature has primarily considered the issue of capitalization from an earnings management perspective; our findings highlight the need for researchers to consider other dimensions of capitalization.

Fourth, prior work on the relationship between R&D investment and financial leverage has assumed that the way in which R&D investment is financed stays constant over time [20,22,27]. However, our findings clearly show that when R&D is successful, that success influences the firm's decision regarding its financing choices. In this sense, we highlight the intertemporal nature of the relationship between R&D investment, financial leverage, and R&D innovation success

Fifth, extant research on R&D investment and financial leverage focus on a single country—for example, the US [21], the UK [5], South Korea [69]. However, we extend prior work by exploring the relationship between R&D investment, leverage, and R&D innovation success in a multi-country setting.

Sixth, our work contributes to the literature on open innovation. Information sharing between firms is a key characteristic of open innovation [23,49,70]. When firms are successful in their R&D innovation activities and signal this success via capitalization of R&D expenditures, firms typically share detailed information about the nature of their success in the notes accompanying their financial statements [3]. Not only is this information sharing a core part of the accounting rules associated with capitalization [8] but many studies show that firms go beyond the basic requirements by including detailed information about the nature of their R&D innovation success [9,21,41,68].

6. Conclusions

We conclude our work by providing two specific recommendations for policy-makers arising from our work. We subsequently proceed to outline several potentially fruitful avenues for future research.

The first of our policy recommendations is to encourage US capital market regulators and the US accounting profession to consider the informational benefits arising from the capitalization of R&D expenditures when firms achieve R&D innovation success. As we noted earlier, accounting for R&D under US GAAP [31] differs significantly from the policy adopted by the international accounting community under IAS 38: *Intangible Assets* [8]. Our work clearly demonstrates the multifarious benefits of the approach used by the international accounting community [71] and as such, we trust that our findings provide food for thought for the US regulatory and financial reporting communities.

The second policy recommendation arising from our work is to highlight the benefits of R&D capitalization from a corporate governance perspective [72]. Our work shows that providers of loan finance take cognizance of the information about R&D innovation success revealed by capitalization. This information can help ensure further financing for R&D projects and can have consequent knock-on benefits from an open innovation systems perspective as discussed earlier. These benefits are potentially non-trivial from an environmental and social perspective. Consequently, board members should encourage firms to capitalize R&D expenditures whenever capitalization is appropriate, and the board should ensure that adequate information about the nature of the firm's R&D innovation success is made available in the notes to the financial statements. Consequently, the board could devise a policy whereby the board's audit committee [73] is made explicitly responsible for ensuring full compliance with the capitalization requirements of IAS 38 and, simultaneously, adopting a generous level of disclosure commiserate with maximizing societal benefits from an open innovation dynamics standpoint.

Turning to potential avenues for future research arising from our study, we noted earlier that the US GAAP rules for accounting for R&D prohibit the capitalization of any R&D [31]. Our results clearly show that the signal emanating from the capitalization of R&D is a crucial influence on a firm's financing strategy. Consequently, future work needs to explore the benefits from a loan-creditor perspective of bringing US GAAP in line with IFRS in accounting for R&D.

More broadly, future research also needs to explore whether accounting for *intangible assets* under US GAAP is optimal to provide best-in-class information to external financial statement users. Given the success of IAS 38 [8] documented here and in other studies [5], this is a matter requiring urgent attention from academics in the field. Our findings also suggest that future research could significantly contribute to the debate surrounding the capitalization of expenditures on other intangibles, such as brand building and brand maintenance [67]. Extant research focuses on how stock-market participants react to information about expenditures on customer satisfaction and brand-building endeavors [14]. Our work suggests that the accounting treatment of these items may also have implications for the banking and debt financing communities. Earlier, we highlighted the way in which R&D capitalization can contribute to open innovation within firms and industries [49]. More work on the role of accounting disclosures within the realm of open innovation networks [12,47,49] could add significantly to our knowledge in this arena. Finally, our research points to the importance of IAS 38 from the perspective of the R&D financing decision. Future work is needed to ensure that IAS 38 remains up-to-date in today's rapidly changing R&D environment characterized by big data [74], risk [75], and ever more complex inter-firm research discovery paradigms [2,11].

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