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WHAT DRIVES INNOVATION CAPABILITY?

– EXECUTIVE BACKGROUNDS, R&D PERSISTENCE, AND FIRM PERFORMANCE IN FINNISH PUBLIC COMPANIES

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WHAT DRIVES INNOVATION CAPABILITY?

– Executive Backgrounds, R&D Persistence, and Firm Performance in Finnish Public Companies

This study examines how top-management characteristics relate to firms' R&D intensity, profitability, and growth in Finnish publicly listed companies. Using an 11-year panel dataset of 27 firms, the analysis focuses on executives' education level and field of study, gender, tenure, and turnover, and evaluates whether these attributes explain strategic investment in R&D or subsequent financial outcomes. The study also investigates how R&D intensity contributes to return on invested capital (ROI) and revenue growth across multiple time horizons.

Panel-data models with lag structures of 1, 3, and 5 years are estimated using pooled OLS with Driscoll–Kraay standard errors to account for heteroskedasticity, autocorrelation, and cross-sectional dependence. The results show that R&D intensity is a highly persistent, firm-specific process: lagged R&D intensity consistently exhibits coefficients near unity, dominating the explanatory power of the models. Governance variables—including executives' education field, education level, gender, tenure, and turnover—do not systematically explain R&D intensity or revenue growth, and the few significant effects are small, inconsistent, and not robust across lag structures.

In contrast, R&D intensity has a strong and economically meaningful association with profitability. Across all models, higher lagged R&D intensity predicts substantially higher ROI, with coefficients ranging from 13 to 17 across the different lag structures. Revenue growth models show lower explanatory power overall, and governance variables again fail to produce systematic effects, while firm size emerges as the only consistently positive but modest predictor.

Overall, the findings indicate that executive background characteristics do not meaningfully shape firms' R&D strategies or growth trajectories. Instead, R&D intensity itself is the key driver of financial performance, highlighting the strategic importance of sustained investment in innovation for Finnish listed companies.

KEYWORDS:

Corporate Governance; Top Management Characteristics; R&D Intensity; Innovation Investment; Firm Performance; Panel Data; Return on Investment (ROI).

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MIKÄ OHJAA INNOVAATIOKYKYÄ?

– Johtajien taustat, T&K-panostusten jatkuvuus ja yritysten suorituskyky suomalaisissa pörssiyhtiöissä

Tämä tutkimus tarkastelee, miten ylimmän johdon taustatekijät liittyvät yritysten T&K-intensiteettiin, kannattavuuteen ja kasvuun suomalaisissa pörssiyhtiöissä. Hyödyntämällä 11 vuoden paneeliaineistoa 27 yrityksestä analyysi keskittyy johtajien koulutustasoon ja koulutusalojen eroihin, sukupuoleen, toimikauden pituuteen ja vaihtuvuuteen sekä arvioi, selittävätkö nämä tekijät strategisia T&K-investointeja tai niiden myöhempiä taloudellisia vaikutuksia. Lisäksi tutkimus tarkastelee, miten T&K-intensiteetti vaikuttaa sijoitetun pääoman tuottoon (ROI) ja liikevaihdon kasvuun eri aikaviiveillä.

Paneeliaineistoa analysoidaan 1, 3 ja 5 vuoden viiveluonteisilla malleilla käyttäen pooled OLS -menetelmää ja Driscoll–Kraay-vakioituja keskivirheitä heteroskedastisuuden, autokorrelaation ja poikkileikkausriippuvuuden huomioimiseksi. Tulokset osoittavat, että T&K-intensiteetti on erittäin pysyvä ja yrityskohtainen prosessi: viivästetty T&K-intensiteetti saa johdonmukaisesti lähes yhden suuruisia kertoimia ja hallitsee mallien selitysvoimaa. Hallinnointimuuttujat — kuten johtajien koulutusala ja -taso, sukupuoli, toimikausi ja vaihtuvuus — eivät systemaattisesti selitä T&K-intensiteettiä tai liikevaihdon kasvua, ja harvat tilastollisesti merkitsevät vaikutukset ovat pieniä, epäjohdonmukaisia ja herkkiä mallien viiverakenteelle.

Sen sijaan T&K-intensiteetillä on vahva ja taloudellisesti merkittävä yhteys kannattavuuteen. Kaikissa malleissa korkeampi viivästetty T&K-intensiteetti ennustaa selvästi parempaa ROI:ta, ja kertoimet vaihtelevat 13–17 välillä eri viivelagien yli. Liikevaihdon kasvua selittävät mallit ovat kokonaisuutena heikompia, eikä hallinnointimuuttujilla ole johdonmukaisia vaikutuksia; yrityksen koko on ainoa säännöllisesti positiivinen mutta maltillinen selittäjä.

Tulokset viittaavat siihen, että johtajien taustatekijät eivät muodosta merkittävää selittävää tekijää yritysten T&K-strategioille tai kasvupoluille. Sen sijaan T&K-intensiteetti itsessään on keskeinen taloudellisen suorituskyvyn ajuri, mikä korostaa pitkäjänteisten innovaatioinvestointien strategista merkitystä suomalaisille pörssiyhtiöille.

ASIASANAT:

Yritysten hallinnointi; Ylimmän johdon taustatekijät; T&K-intensiteetti; Innovaatioinvestoinnit; Yrityksen suorituskyky; Paneeliaineisto; Sijoitetun pääoman tuotto (ROI)

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VAD STYR INNOVATIONSFÖRMÅGA?

– Ledningsbakgrund, FoU-uthållighet och företagsresultat i finländska börsbolag

Denna studie undersöker hur egenskaper hos högsta ledningen relaterar till företagens FoU-intensitet, lönsamhet och tillväxt i finländska börsnoterade företag. Med ett elvaårigt paneldatamaterial omfattande 27 företag analyseras verkställande direktörers och styrelseordförandes utbildningsnivå och utbildningsområde, kön, tjänstgöringstid och omsättning, samt huruvida dessa attribut kan förklara strategiska FoU-investeringar eller efterföljande finansiella utfall. Studien analyserar även hur FoU-intensitet bidrar till avkastning på investerat kapital (ROI) och omsättningstillväxt över flera tidsperioder.

Paneldatamodeller med eftersläpningar på 1, 3 och 5 år estimeras med pooled OLS och Driscoll–Kraay-standardfel för att hantera heteroskedasticitet, autokorrelation och tvärsnittsberoende. Resultaten visar att FoU-intensitet är en mycket uthållig och företagspecifik process: eftersläpade FoU-värden uppvisar konsekvent koefficienter nära ett, vilket dominerar modellernas förklaringskraft. Styrningsvariabler — inklusive ledningens utbildningsområde, utbildningsnivå, kön, tjänstgöringstid och omsättning — förklarar varken FoU-intensitet eller omsättningstillväxt på ett systematiskt sätt, och de få signifikanta effekter som förekommer är små, inkonsekventa och inte robusta mellan olika eftersläpningar.

Däremot har FoU-intensitet ett starkt och ekonomiskt betydelsefullt samband med lönsamhet. I samtliga modeller predicerar högre eftersläpad FoU-intensitet avsevärt högre ROI, och koefficienterna varierar mellan 13 och 17 över de olika laggstrukturerna. Modellerna för omsättningstillväxt uppvisar generellt lägre förklaringskraft, och styrningsvariablerna ger återigen inga systematiska effekter, medan företagsstorlek framträder som den enda konsekvent positiva men måttliga prediktorn.

Sammantaget indikerar resultaten att ledningsbakgrund inte i någon större utsträckning formar företagens FoU-strategier eller tillväxtbanor. I stället framstår FoU-intensitet i sig som den centrala drivkraften bakom finansiell prestation, vilket understryker den strategiska betydelsen av uthålliga innovationsinvesteringar för finländska börsbolag.

NYCKELORD:

Corporate Governance; Ledningsegenskaper; FoU-intensitet; Innovationsinvesteringar; Företagsresultat; Paneldata; Avkastning på investerat kapital (ROI).

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LIST OF ABBREVIATIONS, SYMBOLS AND VARIABLES

List of Abbreviations

Abbreviation	Explanation
CEO	Chief Executive Officer
Chair	Chair of the Board
CSR	Corporate Social Responsibility
CSRD	Corporate Sustainability Reporting Directive
DSCF	Dwass–Steel–Critchlow–Fligner
EPS	Earnings per Share
EU	European Union
FE	Fixed Effects (panel-data estimator)
IFRS	International Financial Reporting Standards
MBA	Master of Business Administration
MM	Master of Management (Indonesian degree: *Magister Manajemen*)
OLS	Ordinary Least Squares
R&D	Research and Development
RE	Random Effects (panel-data estimator)
ROA	Return on Assets
ROE	Return on Equity
ROI	Return on Investment
TE500	Talouselämä 500 – annual ranking of the 500 largest companies in Finland

List of Symbols and Variables

Symbol / Variable	Explanation
Change / Turnover	Indicator for CEO/Chair change in a given year
Econ	Executive’s education in economics or business
Edu_Field	Executive’s field of education (dummy-coded)
Edu_Level	Highest completed degree (0–3)
Gender	Executive gender (1 = female, 0 = male)
$Growth_t$	Logarithmic revenue growth over 1, 3, or 5 years
Juridic	Executive’s education in law
ln_revenue	Natural logarithm of firm revenue
Multi	Executive with multiple educational fields
NSTE	Executive’s education in natural sciences, technology, or engineering

Symbol / Variable	Explanation
Other	Executive’s education in fields outside the main categories
RD_intensity	R&D expenditure / revenue
RD_{t-k}	Lagged R&D intensity (k = 1, 3, 5)
ROI	Return on investment
ROI_{t-1}	Lagged return on investment
Tenure	Years in role as CEO or Chair
β, γ, δ	Regression coefficients (main, governance, control variables)
ε	Error term

Model-Specific Notation

Notation	Explanation
$Y_{i,t}$	Dependent variable for firm *i* at time *t*
$X_{i,t}$	Vector of explanatory variables
α	Intercept
β	Coefficient vector
$\varepsilon_{i,t}$	Error term for firm *i* at time *t*

1 INTRODUCTION

In recent years, a series of global shocks has reshaped the economic environment in ways that underscore the strategic importance of corporate investment. The COVID-19 pandemic, Russia's invasion of Ukraine, and escalating geopolitical tensions in the Middle East have increased uncertainty, disrupted supply chains, and heightened financial-market volatility. In such an environment, firms' ability to sustain long-term investment in research and development (R&D) has become a critical source of competitiveness and economic resilience.

Finland enters early 2026 in a position where these global shocks have hit an economy already weakened by structural challenges. Unemployment has risen to historically high levels, economic growth has stalled, and the sustainability of public finances has deteriorated to the point where core public services increasingly rely on debt financing. Recent analysis shows that Finland's economic weakness does not stem from any single crisis, but from a prolonged stagnation in productivity, persistently low investment levels, and structural rigidities that have made the economy vulnerable to external shocks (Pohjola, 2025). Although recent crises have intensified these pressures, Finland's economic problems are not new. Assessments by the Organisation for Economic Co-operation and Development (OECD) indicate that Finland entered the recession of the early 1990s from an already imbalanced position: the economy overheated in the late 1980s, domestic demand surged, inflationary pressures mounted, and external balances deteriorated (OECD, 1989). When exports contracted and competitiveness weakened, the economy plunged into a deep recession, with output falling exceptionally sharply (OECD, 1991, 1992). The OECD also highlighted structural issues — including regulatory distortions, weak competition, and fiscal rigidities — that slowed recovery and persisted well beyond the crisis (OECD, 1991, 1992, 1993).

The economy rebounded in the mid-1990s, and Nokia's rapid rise created an exceptionally strong but narrow growth engine (Ali-Yrkkö, 2010; OECD, 1995; OECD Publishing, 2006). While technological success boosted productivity and exports, it also masked the fact that Finland's growth became increasingly concentrated in a few sectors, reducing the economy's structural diversity. Nokia's decline in the late 2000s exposed these vulnerabilities just before the global financial crisis (Ali-Yrkkö, 2010). Subsequent OECD reports show that Finland has struggled to return to its pre-crisis growth trajectory: productivity growth stalled, investment remained subdued, and economic performance lagged behind peer countries (OECD, 2008, 2014; OECD Publishing, 2010). According to the Finnish Innovation Fund Sitra, Finland's weak economic performance is not driven by the size of the public sector but by low productivity, insufficient investment, and particularly inadequate R&D spending (Åkerholm, 2024). The COVID-19 pandemic and Russia's war in Ukraine have further increased uncertainty, tightened fiscal constraints, and reinforced the picture of an economy facing both short-term shocks and long-term structural challenges (OECD, 2020, 2022, 2025).

At the same time, firms operate under intensifying sustainability and environmental-responsibility requirements. EU-level climate and sustainability regulation — including the Taxonomy Regulation and CSRD reporting obligations — directs companies to reduce emissions, improve resource efficiency, and account for impacts across their entire value chains. These pressures extend beyond environmental footprints to encompass workplace ethics, employee well-being, and broader corporate social responsibility. Firms must increasingly develop solutions that are economically viable, environmentally sustainable, and socially acceptable — a shift that further elevates the strategic importance of R&D.

Against this economic and geopolitical backdrop, investment in research and development has become one of the few mechanisms capable of restoring productivity and long-term growth. Sitra's recent analysis shows that Finland's future growth depends critically on strengthening innovation capacity and raising R&D spending to internationally competitive levels (Åkerholm, 2024). At the firm level, R&D is a strategic choice shaped by owners, boards, and top management. Understanding who makes these decisions — and the extent to which their backgrounds influence corporate R&D strategies and financial outcomes — is therefore essential.

This question is particularly salient in Finland, where top management is relatively homogeneous in educational background and where institutional norms emphasize cautious risk-taking and long-term prudence. It remains unclear whether executives' education level, field of study, gender, tenure, or turnover influence firms' R&D intensity and growth — or whether these strategic investments are primarily driven by firm-specific structures and owner preferences. Sitra's Megatrends 2026 report highlights that Finland's future competitiveness will increasingly depend on skills, technological capabilities, and the strength of the innovation system — all of which are directly linked to firms' R&D strategies (Dufva & Kiiski-Kataja, 2026).

The author of this study has a research background in the natural sciences and engineering and is particularly interested in the role of R&D in shaping both firm-level performance and national economic outcomes. The aim of this research is to provide empirical evidence on how top-management characteristics, R&D intensity, and corporate financial performance are related in Finnish publicly listed companies. The analysis draws on an 11-year panel dataset covering 27 firms, providing a solid basis for examining long-term patterns in strategic decision-making within the Finnish context.

This study fills three gaps in the existing literature. First, it examines executives' educational backgrounds in terms of both degree level and field of study, offering a more granular view of managerial human capital. Second, it links these background variables to R&D intensity — a strategic variable far less studied than financial performance. Third, it investigates how R&D intensity relates to both profitability and growth, allowing a distinction between the economic effects of development-oriented versus research-oriented R&D.

The research addresses the following questions:

1. Do top-management characteristics (education level, field of study, gender, tenure, and turnover) explain firms' R&D intensity?
2. Do these characteristics explain firms' revenue growth?
3. How is R&D intensity related to firms' profitability (return on investment, ROI) and growth?

The study employs panel-data methods that account for persistence in variables and potential structural dependencies, enabling a rigorous examination of the relationships between top-management characteristics, R&D intensity, profitability, and growth in Finnish listed companies.

The remainder of this report is structured as follows: Section 2 presents the literature review, Section 3 describes the data and methods, Section 4 provides the exploratory data analysis, Section 5 reports the empirical results, Section 6 discusses their implications, and Section 7 concludes with contributions, limitations, and avenues for future research. The full assessment version of this thesis consists of 351 pages, including 226 pages of technical appendices reviewed during the internal evaluation process. The public Theseus version excludes these appendices in accordance with publication requirements.

2 LITERATURE REVIEW - LEADERSHIP, LEADERS' BACKGROUND AND FIRM PERFORMANCE

Research on leadership, board composition, and corporate governance provides a multidimensional explanation for why firms differ in financial performance across institutional settings. Broad governance indicators, such as the Gov-Score index (Brown & Caylor, 2004), are consistently associated with higher profitability and firm value, while executive and board compensation structures help account for performance variation. Managerial educational background can also matter: in Indonesian listed firms, postgraduate degrees and prestigious universities improve return on assets (ROA) and Tobin's Q, whereas a high concentration of finance degrees in the top management team may weaken performance (Darmadi, 2011).

Board structure remains a central determinant of firm outcomes. In India, larger boards and a higher proportion of outside directors are linked to stronger financial performance, while CEO duality does not weaken results, challenging core agency-theory assumptions (Jackling & Johl, 2009). Evidence from Jordan similarly shows that board independence, CEO duality, managerial ownership, and international diversity support performance, whereas a highly educated board may unexpectedly reduce it (Kanakriyah, 2021). Committee leadership also matters: the chairs of audit, compensation, and nominating committees jointly explain nearly one-fifth of the variation in firm performance, with their influence increasing under tighter regulatory environments (Kolev et al., 2025).

Board diversity produces mixed effects, improving accounting-based performance but weakening market-based performance depending on board independence, CEO duality, board size, and institutional conditions (Pandey et al., 2023). Leadership succession dynamics further shape performance trajectories. When the outgoing CEO remains as board chair, their continued influence constrains the successor's strategic discretion, reducing strategic change and keeping performance close to the predecessor's tenure. When the predecessor exits entirely, the new CEO gains autonomy, leading to greater strategic change and higher performance variability (Quigley & Hambrick, 2012). Trust between the board chair and CEO also matters: higher interpersonal trust improves ROE, ROA, and net profit margin (NPM), strengthens the positive effects of R&D investments, and mitigates the negative consequences of CEO turnover (Zheng & Zhu, 2019).

Recent research further highlights how turnover-related mechanisms interact with governance structures and institutional environments. Farrell et al. show that CEO duality —an arrangement closely tied to CEO turnover dynamics—is the board attribute most sensitive to national culture. Its performance effects vary substantially across cultural contexts and performance metrics: in some cultures, CEO duality aligns with agency-theory predictions of weaker oversight, while in others it supports stewardship-type outcomes and stronger performance. The strongest empirical alignment appears in collectivist contexts, whereas uncertainty-avoidant environments favor agency-aligned structures, demonstrating that structural changes to the CEO role affect performance only in culturally contingent ways (Farrell et al., 2026).

At the country-institutional level, Borges et al. find that firm performance is shaped primarily by the quality of the national governance environment rather than internal turnover mechanisms. Firms operating in countries with stronger governance—characterized by lower corruption, more effective institutions, and better regulatory quality—achieve higher performance, and cultural context further strengthens this relationship. Thus, external institutional stability and cultural alignment, rather than leadership turnover, explain performance differences across countries (Borges et al., 2023).

Internal leadership characteristics also matter. Al Mutairi and Bakar show that CEO integrity significantly strengthens the positive effect of corporate reputation on firm performance (ROA, ROE, Tobin’s Q), while ownership concentration enhances the formation of corporate reputation through corporate social responsibility disclosure. These findings indicate that internal leadership quality and ownership structure shape how reputational mechanisms translate into financial outcomes, functioning as turnover-relevant moderators of performance (Al Mutairi & Bakar, 2023).

A more direct turnover mechanism emerges in state-owned enterprises. Prior research demonstrates that while board members’ education and experience generally do not affect performance, leadership turnover that brings in managers without industry experience has a consistently negative impact on ROA and ROE. This effect remains robust across multiple model specifications and endogeneity checks, indicating that “wrong-type” managerial turnover—where incoming leaders lack sector-specific knowledge—harms financial performance, whereas other forms of board or leadership turnover show no measurable effect (Sidki et al., 2024).

2.1 CEO Education and Firm Performance

2.1.1 Mixed Evidence on the Performance Effects of CEO Education

The empirical literature demonstrates that the relationship between a Chief Executive Officer's (CEO's) educational background and firm performance is highly heterogeneous. Early and widely cited studies challenge the assumption that elite education or specific degree types systematically translate into superior corporate outcomes. Gottesman and Morey report that neither school prestige nor holding a Master of Business Administration (MBA) or law degree predicts market- or accounting-based performance measures such as excess returns, alpha, return on assets (ROA), return on equity (ROE), or Tobin's Q. Similarly, Jalbert et al. find that school ranking, degree type, and MBA status do not explain ROA, ROE, or return on investment (ROI), even though CEOs from elite institutions receive higher compensation on average (Gottesman & Morey, 2006; Jalbert, Furumo, et al., 2011; Jalbert, Rao, et al., 2011).

More recent studies reinforce the view that education has limited explanatory power for firm performance. Using a large U.S. dataset, it has been shown that CEO education does not systematically predict firm financial outcomes, despite its association with compensation (Jalbert, Furumo, et al., 2011) Other research likewise finds that elite education does not improve CEO performance in the United States, France, or Sweden, and that the overrepresentation of elite-educated CEOs reflects social privilege rather than superior ability (Atkinson & Blundell-Wignall, 2021). Additional evidence indicates that CEO education does not consistently affect firm performance in European listed companies, regardless of the ranking system or performance metric used (Morresi, 2017). Further work shows that education does not explain CEO dismissal or long-term firm performance, although it does influence the selection of successor CEOs (Bhagat et al., 2010).

Not all educational backgrounds are equally advantageous. In Japan, CEOs educated at corporate universities systematically underperform those from traditional universities, delivering lower ROA and weaker sales growth (Nguyen & Fan, 2022).

2.1.2 Positive Effects in Specific Contexts and Educational Profiles

Despite the predominance of null findings, several studies document positive effects of CEO education in specific institutional environments and educational profiles. Holding a degree and graduating from a higher-ranked university are associated with higher ROA and Tobin's Q (Jalbert, Rao, et al., 2011). In Indonesian LQ45 firms, educational backgrounds in business, finance, management, and accounting improve firm market value, with effects strengthened by postgraduate degrees and foreign education (Silvina et al., 2022).

Institutional context plays a substantial role. In the Nigerian financial sector, CEOs with postgraduate degrees improve profitability measured by ROA, and higher educational attainment—particularly in finance, economics, and management—is positively and significantly associated with ROA (Saidu, 2019; Yahaya, 2025). In Indonesian manufacturing firms, MBA/MM education reduces leverage, increases investment, and enhances profitability (Setiawan & Gestanti, 2022).

A notable exception to the generally weak findings is that CEOs holding a doctoral degree (PhD) improve firm performance by an average of 3.03%, with the effect rising to 4.65% when the degree is from a QS Top 100 university. These effects are attributed to tighter cost control and superior cash-flow management (Urquhart & Zhang, 2022).

2.1.3 Education Explains Compensation Better Than Firm Performance

One of the most consistent findings in the literature is that education explains CEO compensation far better than firm performance. Elite education and MBA status are more strongly associated with pay levels than with firm outcomes (Gottesman & Morey, 2006; Jalbert, Furumo, et al., 2011). Education similarly influences compensation but not financial performance (Jalbert, Furumo, et al., 2011). Elite education also does not enhance market-based firm value, despite its prevalence among top executives (Atkinson & Blundell-Wignall, 2021).

2.1.4 Cognitive Ability, Personality and Learning Agility as Explanatory Mechanisms

Meta-analytic evidence provides a compelling explanation for why CEO education alone is a weak predictor of firm performance. First, cognitive intelligence and personality are largely independent constructs, each contributing differently to job performance. Personality traits—particularly openness to experience—add meaningful incremental validity beyond cognitive intelligence in predicting work performance. This indicates that neither intelligence nor educational attainment alone captures the full range of attributes relevant for executive effectiveness (Martínez et al., 2025).

Second, learning agility—the ability to learn quickly and apply learning in new situations—is one of the strongest predictors of leadership success. Learning agility predicts both leader performance and leader potential more strongly than cognitive intelligence or emotional intelligence. High learning agility clearly differentiates high-potential leaders from others, underscoring its importance in executive selection and development (De Meuse, 2019).

Third, the relationship between cognitive intelligence and leadership is positive but only moderately strong and highly context-dependent. Intelligence predicts leadership more effectively in low-stress and directive contexts, but not in high-stress or participative environments. This suggests that the impact of intelligence on leadership effectiveness is situational rather than universal (Judge et al., 2004).

Taken together, these meta-analyses show that executive performance is shaped by multiple, largely independent factors—such as personality, cognitive ability, and learning agility—that are not directly captured by educational background. This helps explain why CEO education is an unreliable proxy for managerial ability and why its relationship with firm performance is inconsistent across studies.

2.1.5 Section Summary

The literature on CEO education and firm performance presents a highly fragmented picture. While some studies identify positive effects in specific contexts—such as certain fields of study, emerging markets, or doctoral-level education—the majority of research finds no systematic relationship between educational background and firm-level outcomes. Education consistently explains compensation more effectively than performance, suggesting that labor markets reward credentials even when firms do not. Meta-analytic evidence further clarifies that executive effectiveness depends on attributes such as personality, cognitive ability, and learning agility, which education does not directly measure. As a result, CEO education alone offers a limited and context-dependent basis for predicting firm performance.

2.2 Chair Education and Firm Performance

Scholarly work on board leadership highlights that the board chair's influence on firm performance is far more strategic and multifaceted than traditionally assumed in corporate governance research. A comprehensive review of chair-focused research demonstrates that although the chair's role has in practice evolved into a strategic, multifaceted, and demanding position, academic research remains theoretically and methodologically narrow, concentrating primarily on CEO–chair duality and financial outcomes. According to the review, the chair influences board effectiveness, decision-making, dynamics, and the relationship with the CEO, but findings on financial effects are inconsistent and no unequivocal link has been established. In non-financial dimensions, the chair's role is particularly salient in stakeholder relations, reputation, responsibility, and crisis leadership, and the literature highlights that evidence on chair competencies is fragmented and focused on demographic factors, whereas everyday leadership practices and interaction with the CEO remain under-researched (Banerjee et al., 2020).

Empirical evidence confirms that the chair has an independent and substantial impact on firm financial performance. According to Withers and Fitza, chair-specific effects explain roughly nine percent of the variation in firm outcomes, a magnitude comparable to the CEO effect. The effect is not derivative of the CEO but reflects the chair's role as an autonomous strategic decision-maker. The chair's importance is particularly pronounced in resource-constrained and complex environments where mobilizing external resources is critical, whereas in dynamic environments the effect was not statistically stronger as expected, although the direction was similar (Withers & Fitza, 2017).

Research on chair education is considerably more limited and the findings clearly more contradictory. Phan finds no empirical evidence that the educational level of board members or the chair affects firm performance in either the short or long term. Although better-educated boards may appear to deliver stronger short-term results, this advantage is not sustained and later reverses, suggesting that formal education is not a reliable indicator of the chair's advisory or leadership capability. The study emphasizes that educational degrees are often obtained long before board appointments, meaning that other cognitive resources—such as industry experience and networks—better capture the chair's actual competence (Phan, 2016).

Chair competence has also been examined within the framework of board human capital. Lin et al. show that board human capital is clearly and statistically significantly associated with firm performance, particularly commitment-oriented human capital (such as board ownership), which improves net asset value per share. The chair's own human capital does not directly explain performance, but it plays a significant moderating role: the chair's capability-oriented human capital strengthens the positive effect of the board's capability-oriented human capital and simultaneously weakens the effect of commitment-oriented human capital, resulting in statistically significant but directionally opposite moderation effects (Lin et al., 2006).

Contextual differences influence the extent to which chair competence or education is reflected in firm performance. In Indonesian manufacturing firms, corporate governance factors—including the chair's competence—do not explain earnings management, and the only significant effects relate to firm size and profitability, while the model's explanatory power remains very low. This underscores that the chair's influence does not necessarily appear in all financial metrics or in all institutional environments (Natasya, 2022).

Overall, the literature shows that the board chair's impact on firm performance is substantial but multilayered. Although formal education does not appear to be a consistent predictor of performance, the chair's strategic role, human capital, and ability to influence the board's collective competence are key mechanisms through which the chair affects firm success (Banerjee et al., 2020; Lin et al., 2006; Natasya, 2022; Phan, 2016; Withers & Fitza, 2017).

2.3 Effect of Tenure on Leadership

A substantial body of research demonstrates that CEO and board tenure affect firm performance through complex, often non-linear mechanisms that evolve over the leadership life cycle. Several studies emphasize that tenure is not a neutral background variable; rather, the leadership life cycle shapes both firm financial outcomes and the board's monitoring and decision-making.

CEO tenure is clearly associated with firm financial performance: longer tenure systematically affects return on assets (ROA), earnings per share (EPS), and pretax income, and the effect is statistically significant across all models. This indicates that firm profitability and earnings capacity evolve as the CEO's career progresses, and tenure is not neutral with respect to performance (Ahamed, 2015). However, the effect of tenure is not linear. Firm value (Tobin's Q) increases during the early years of a CEO's tenure due to learning and accumulated experience, but turns downward after approximately 10–12 years as risk aversion, resistance to change, and entrenchment weaken decision-making. This inverted U-shaped relationship also appears in ROA models, in the value effects of M&A decisions, and in market reactions to sudden CEO deaths, where the death of a short-tenured CEO generates negative abnormal returns and the death of a long-tenured CEO generates positive abnormal returns (Limbach et al., 2016). Similar results are reported by Brochet et al., who find that firm value increases early in the CEO's career but declines later, and that optimal tenure is shorter in dynamic industries and in situations where the CEO becomes entrenched. Moreover, the quality of financial reporting deteriorates as tenure progresses, reflected in a hump-shaped pattern in accrual quality and a U-shaped probability of restatements (Brochet et al., 2021).

Tenure effects also appear in firm growth metrics. Barba Navaretti et al. show that firms led by younger CEOs (under 45) grow organically significantly faster than those led by older CEOs: median sales growth is 0.66 log points and asset growth 0.52 log points higher per time unit, reflecting substantially stronger organic growth under younger leadership. This negative relationship between CEO age and organic growth persists after extensive controls but does not extend to operating profit growth. The study also shows that ownership concentration weakens the growth orientation of younger CEOs, indicating the importance of incentives (Barba Navaretti et al., 2022).

Tenure also affects how the board responds to CEO performance. According to Dikolli et al., poor performance leads to CEO turnover far more frequently early in the CEO's career than later. Long-tenured CEOs are substantially less sensitive to performance-based dismissal, and monitoring weakens as tenure increases: board meetings decline, board independence decreases, CEO ownership rises, and the likelihood of serving simultaneously as board chair increases. At the beginning of a new CEO's tenure, monitoring tightens again, supporting a model in which uncertainty about CEO ability diminishes over time and leads to a "statistical entrenchment" effect (Dikolli et al., 2014).

Tenure can also strengthen firms' strategic and responsibility-related outcomes. Ghardallou finds that CEO tenure improves firm financial performance across all models (ROA, ROE, Tobin's Q), and that the financial benefits of corporate social responsibility (CSR) activities increase with tenure. The CSR × Tenure interaction term is consistently positive and significant, indicating that long-tenured CEOs leverage CSR initiatives more effectively to support long-term firm success (Ghardallou, 2022).

Tenure effects are not limited to CEOs but also apply to board members. According to Bonini et al., long-tenured independent directors (≥15 years) consistently improve firm performance across multiple measures, with particularly strong effects in complex and mature firms and in cases where the long-tenured director has served under multiple CEOs. Market reactions to the death of a long-tenured independent director are negative, and such firms experience fewer shareholder lawsuits and activist interventions, indicating stronger governance and oversight (Bonini et al., 2022). Board-average tenure affects firm value in an inverted U-shaped manner: Tobin's Q and ROA improve up to roughly 10 years of tenure but decline thereafter due to entrenchment. This relationship also appears in M&A decisions, reporting quality, and CEO compensation, and sudden-death events reinforce the causal interpretation (Huang & Hilary, 2018). In addition, tenure diversity—the heterogeneity of tenures within the board—improves firm performance in both Tobin's Q and ROA models, whereas diversity in educational background has no effect. Tenure diversity balances the advantages of short and long tenures and produces a more effective board (Magnanelli et al., 2021).

2.4 Turnover and Firm Performance

Empirical studies on CEO and board turnover consistently show that its performance implications depend on the nature, timing, and contextual fit of the leadership change rather than the mere occurrence of turnover. Several studies emphasize that turnover does not in itself improve or weaken performance; rather, the effect arises from the circumstances under which the change occurs and the characteristics of the successor.

According to Allgood and Farrell, firm performance affects the likelihood of forced CEO turnover differently across the CEO’s career cycle. For newly appointed CEOs, poor performance more readily leads to forced turnover, whereas during mid-tenure the effect weakens, indicating entrenchment and reduced board responsiveness. After long tenure, the effect strengthens again. The pattern also varies by CEO type: for inside CEOs, the performance effect is stable; founder CEOs are protected during their first ten years; and outside CEOs experience a strict probation period, an entrenchment phase, and eventually increasing performance sensitivity (Allgood & Farrell, 2000). The performance effects of turnover also depend on whether the change is disciplinary or voluntary. According to Bhagat et al., in disciplinary turnovers short-term operating performance improves only when the new CEO holds a Master of Business Administration (MBA) degree, whereas other degrees have weak or negative effects. In voluntary turnovers, CEO educational background has no effect, and long-term performance (ROA, stock returns, Tobin’s Q) does not change systematically based on CEO education (Bhagat et al., 2010).

Turnover can improve performance particularly when it functions as a disciplinary mechanism. In the study by Dasgupta et al., forced CEO turnover improves operating performance and total factor productivity (TFP) following industry-specific competitive shocks, such as tariff cuts. No improvement is observed after voluntary turnovers, and firms experiencing forced turnover more often hire CEOs with experience in low-cost and divestment environments, supporting efficiency-enhancing actions (Dasgupta et al., 2014). Further evidence highlights the importance of turnover type: interim CEO appointments weaken operating performance only in voluntary turnovers, whereas in forced turnovers interim appointments do not reduce ROA or market-based performance (Intintoli et al., 2014).

The effect of turnover also depends on how the departure type of the outgoing CEO and the background of the successor interact. Khurana and Nohria show that forced turnover combined with outsider succession improves performance because the forced departure creates organizational disruption and the outsider successor can implement change. Natural turnover combined with insider succession does not affect performance, as it is the least disruptive transition. Natural turnover combined with outsider succession weakens performance due to internal resistance, and forced turnover combined with insider succession weakens performance because change is expected but the insider is unable to deliver it (Khurana & Nohria, 2000).

The effects of board turnover are similarly context-dependent. According to Bolton and Park, replacing only the board chair reduces earnings before interest and taxes (EBIT) growth, and long chair tenure is also negatively associated with performance. In contrast, simultaneous turnover of the chair and other board members significantly improves EBIT growth, suggesting that board renewal affects firm outcomes only when the change is sufficiently broad (Bolton & Park, 2021). The study by Park and Bolton complements this by showing that a new chair increases the likelihood of director departures, although family ownership and dual-class structures attenuate this effect. While the study does not examine financial performance, it demonstrates that turnover reshapes board dynamics and governance processes (Park & Bolton, 2022).

2.5 Gender Effect and Leadership

Research on gender and leadership underscores that gender-related effects on firm performance are multidimensional and strongly contingent on organizational and contextual factors. Gender does not in itself determine a firm's financial success, but gender transitions, gender composition, and the interaction between gender and organizational context can produce significant differences in firm outcomes.

2.5.1 Gender transitions in CEO turnover

A change in CEO gender is one of the most consistently performance-relevant factors. Bozionelos et al. show that firm performance declines specifically when the incoming CEO's gender differs from that of the predecessor (male→female or female→male), whereas same-gender successions (male→male or female→female) do not generate negative effects. The decline is not caused by female leadership per se but by the transition itself, and the effect is mitigated by greater CEO power and state ownership (Bozionelos et al., 2023). Zhang and Qu report similar findings: male→female transitions reduce return on assets (ROA) and increase the risk of early departure for the successor, whereas female→male transitions do not affect ROA but still increase the likelihood of non-routine departure. These negative effects disappear entirely when the organization has other female executives or when the successor is an internal appointment (Zhang & Qu, 2016).

Elsaid adds that female→male transitions improve firm performance and reduce bankruptcy risk, but the effect turns negative when the CEO's role or educational background changes simultaneously. This suggests that "too much change" weakens firm performance (Elsaid, 2014).

2.5.2 Gender and CEO duality

Gender also shapes how CEO–chair duality affects firm performance. La Rocca et al. show that CEO duality improves firm financial performance only when the dual role is held by a woman. The ROA effect of a female dual CEO is clearly positive, whereas male dual CEOs show no effect. The effect is stronger in countries with low gender equality, suggesting that female leaders leverage duality particularly effectively in structurally unequal environments (La Rocca et al., 2024).

2.5.3 Gender and internal resource allocation

Duchin et al. show that male CEOs invest less in divisions led by women: the investment rate is 0.46–0.67 percentage points lower than in otherwise comparable divisions. This absolute difference corresponds to a 9–13 percent reduction relative to the average annual investment level. This reduces divisional growth, profitability, and ultimately firm operating performance and stock returns. The bias is linked to gendered early-life experiences of the CEO, but strong governance—particularly a female board chair—can substantially mitigate it (Duchin et al., 2021).

Newton and Simutin show that male CEOs pay female executives significantly less than male executives, whereas female CEOs do not exhibit such bias. Although the study does not examine firm financial performance, it demonstrates that gender affects internal resource allocation and executive compensation (Newton & Simutin, 2015).

2.5.4 Gender and workforce composition

The effect of gender on firm performance also depends on workforce composition. Flabbi et al. show that female leadership improves productivity only when the firm has a sufficient share of female employees. In firms with an average of 20% women, a female

CEO increases sales per worker by about 3.7%, whereas in firms with few women the effect is weak or negative. Underrepresentation of female leaders generates efficiency losses because their skills are mismatched to firms with too few women (Flabbi et al., 2019).

2.5.5 Board gender composition and firm performance

The effect of board gender composition on firm performance is strongly context-dependent. Female directors can improve financial performance, strengthen monitoring, and reduce agency problems, but the effect may be neutral or negative when appointments are symbolic or the firm is family-owned (Hindasah & Harsono, 2021). The share of women on the board improves firm performance in both Tobin's Q and ROA models, and the effect of independent directors becomes positive only when the board is gender-diverse; even the presence of at least one woman on the board is associated with better performance (Terjesen et al., 2016). The positive effect of gender diversity is limited to small and medium-sized firms, whereas in large firms the effect weakens and may turn negative (H. Li & Chen, 2018). In developed countries the share of women on the board is consistently negatively associated with firm market value, because additional monitoring becomes a cost in environments with strong investor protection (Vo & Bui, 2017). Gender diversity can either promote or hinder strategic change depending on firm conditions and the power of female directors: in non-threat contexts female director power increases strategic change, whereas in threat contexts the same power reduces it (Triana et al., 2014).

2.5.6 Gender, market value, and financing

Gender effects also appear in CEO market valuation and financing. Female CEOs are associated with higher return on investment (ROI), ROA, sales growth, and higher P/E ratios, and the study finds no negative effects on financial metrics (Jalbert et al., 2012).

Markets in Japan react positively to the appointment of the first female CEO, but only founder-background female CEOs are associated with higher market value (Kubo & Nguyen, 2021). In the startup environment, gender effects are particularly pronounced in financing. Male-led teams receive several times more funding than female-led teams, and CEO gender is the strongest predictor of funding success, indicating widespread bias against female CEOs (Cassion et al., 2021).

2.6 Governance and R&D Intensity

Studies examining the governance determinants of R&D investment show that managerial backgrounds, ownership structures, and governance mechanisms shape firms' R&D intensity through complex and frequently non-linear channels. A central finding is that governance can either weaken or strengthen R&D investment—and at times also alter its productivity—depending on the incentives, constraints, and monitoring mechanisms embedded in the firm's governance system.

2.6.1 Managerial backgrounds and psychological traits as determinants of R&D intensity

Several studies show that managers' educational and professional backgrounds directly affect firms' R&D investment. Liu et al. demonstrate that executives with finance backgrounds systematically reduce R&D intensity: they increase financial investments, cut R&D expenditures, and face greater financing constraints, leading to declines in innovation and patenting. The effect is quantitatively large, and strong corporate governance—such as concentrated ownership or institutional ownership—mitigates this crowding-out effect (B. Liu et al., 2020). Psychological traits also shape R&D behavior: Hur et al. show that overconfident CEOs maintain R&D spending during downturns because they optimistically expect future growth and view R&D cuts as costly. This makes R&D expenditures more rigid and sustains higher R&D levels particularly when sales decline (Hur et al., 2019). Technical expertise influences R&D strategy in different ways: CEOs with technical backgrounds internalize R&D outputs into further in-house development and license out less, lengthening development cycles and reducing external commercialization (Ener, 2022).

2.6.2 Ownership structure and financing channels as modifiers of R&D intensity

Ownership structure plays a central role in determining the level and direction of R&D investment. According to Rapp and Udoieva, ownership concentration reduces R&D intensity in emerging markets, particularly when owners have strong control rights and shareholder protection is high. Strategic blockholders—such as the state or holding companies—cut R&D investment, whereas institutional blockholders do not (Rapp & Udoieva, 2017). In the Chinese context, Qian and Yuan show that ownership concentration affects R&D investment non-linearly: moderate concentration increases R&D intensity, but excessive concentration reduces it due to tunneling risk. Managerial stock options modify this relationship: under low concentration, options weaken R&D investment, but under high concentration they mitigate the negative effect of large shareholders (Qian & Yuan, 2023). Financing channels are equally important: Lee shows that R&D investment is highly sensitive to internal cash-flow fluctuations and that debt financing is a more effective R&D funding channel than equity financing. Ownership concentration and foreign ownership increase R&D intensity, whereas institutional ownership has no effect (S. Lee, 2012).

2.6.3 Financialization and regulation as counterforces to R&D investment

Corporate financialization is one of the most consistent factors reducing R&D intensity. Liu and He show that the more a firm allocates resources to financial assets, the less it invests in R&D, and the effect appears in both R&D inputs and innovation outputs. The effect is particularly strong in state-owned enterprises and low-profitability firms (L. Liu & He, 2023). Regulation, however, can reverse this pattern: Gao et al. show that China's New Asset Management Regulation reduced financialization and increased R&D investment, especially in firms that were previously highly financialized. Regulation thus functions as a governance mechanism that redirects firms away from short-term financial activities toward long-term innovation (Gao et al., 2023).

2.6.4 External governance shocks and policy-driven financing

Increasing competition and external pressure can raise R&D activity. Khachoo and Sharma show that the entry of foreign direct investment (FDI) increases the likelihood that both domestic and foreign incumbent firms engage in R&D, although the effect on R&D intensity is modest. Domestic firms increase investment to maintain competitiveness, whereas foreign firms can rely on parent-company technology (Khachoo & Sharma, 2017). Policy-driven financing operates differently: Ge et al. show that governmental venture capital (GVC) funding increases innovation particularly in industries designated as strategic by the state, even though its financial returns are weaker. GVC-funded firms file 14.9% more patent applications than comparable private VC-funded firms because the funding is driven by political incentives rather than market efficiency (Ge et al., 2024).

2.6.5 productivity and slack resources

Governance also affects the productivity of R&D investment. Hwang et al. show that R&D expenditures increase firm market value in both IT and non-IT firms, but only in the IT sector does strong governance—particularly foreign ownership—enhance the value creation of R&D investment. The share of outside directors has no effect on R&D efficiency (Hwang et al., 2013). The quality of slack resources is a key factor: Lee and Wu show that absorbed slack weakens the productivity of R&D investment, whereas unabsorbed slack strengthens it, but only at moderate levels. R&D capital is systematically more productive than short-term R&D expenses, and the type of slack determines whether R&D investment translates into improved performance (C. Lee & Wu, 2016). Stock-based incentive schemes improve the efficiency of R&D investment, whereas government R&D subsidies weaken it, and the two mechanisms do not exhibit complementarity (Z. Li & Yamada, 2025).

2.6.6 Financing constraints, R&D smoothing, and technological capability

Financing constraints are a central governance factor in the dynamics of R&D intensity. Liu et al. show that R&D-intensive firms smooth R&D investment by selling assets, but financing constraints weaken this mechanism. Innovation efficiency strengthens R&D smoothing and can even offset the negative effect of financing constraints (D. Liu et al., 2021). The persistence and variability of R&D investment depend on technological capability: high-capability firms increase R&D investment in positive shocks and maintain it in negative shocks, whereas low-capability firms cut R&D sharply during downturns (Kang et al., 2017). Yin et al. further show that the effect of financing constraints on R&D investment depends on CEO gender and experience. Female CEOs do not reduce R&D spending under internal financing constraints, whereas male CEOs do. Experience mitigates the effect of financing constraints early in the CEO’s career but amplifies it with long tenure (Yin et al., 2019).

2.7 The Effect of R&D Intensity on Firm Performance

The research literature consistently shows that research and development (R&D) intensity is a key driver of firms' financial performance. However, the magnitude, direction, and timing of the effects depend heavily on firm size, industry, technological position, and the broader economic environment. R&D generates both direct productivity and profitability effects as well as indirect benefits through risk premia, increases in market value, and strengthened competitiveness.

2.7.1 Direct effects of R&D investment on profits and productivity

R&D investment improves firm profits and productivity through several mechanisms. Amoroso et al. show that R&D coefficients are positive and significant across all models, and private returns to R&D are strongly positive. Firm-level and industry-level risk increase profits in line with the risk-premium hypothesis, and Knightian ambiguity raises R&D returns through an ambiguity-premium effect, even though it simultaneously reduces profits due to more cautious investment behavior (Amoroso et al., 2017).

R&D productivity also depends on the extent to which firms leverage domestic and foreign R&D. According to Belderbos et al., foreign and domestic R&D are complementary in technologically lagging industries, whereas in industries at the technological frontier only domestic R&D generates significant productivity gains. This underscores the importance of absorptive capacity (Belderbos et al., 2015).

2.7.2 Firm size, risk profile, and variation in R&D returns

Firm size strongly shapes the economic effects of R&D investment. Ciftci and Cready show that large firms generate more future income per R&D dollar because they can spread innovations across a broader sales base. In small firms, R&D increases earnings volatility substantially more, and they earn higher market returns as a risk premium, whereas R&D in large firms is less risky and yields lower market returns (Ciftci & Cready, 2011).

The profitability effects of R&D are also cyclical. Before a crisis, R&D reduces profitability, but during a crisis the effect turns positive: firms that continued R&D

investment during the economic downturn improved profitability and outperformed competitors (Dimitropoulos, 2020).

2.7.3 R&D intensity, market value, and market risk

R&D intensity affects firm market value, but the effect is industry-specific and depends on the economic environment. Market value responds positively to R&D intensity in both manufacturing and services, but the strength of the effect varies across business-cycle and shock environments: before the 9/11 shock the effect was stronger in manufacturing, and after the shock it was stronger in services (Ehie & Olibe, 2010). R&D also increases market risk. Both total and idiosyncratic volatility increase when firms intensify their R&D investment due to information asymmetry, project risk, and rapid technological change (Gharbi et al., 2014).

2.7.4 Financing channels, financial contraints, and the institutional environment

Financing channels determine the extent to which R&D investment translates into financial outcomes. Used credit lines are a key R&D financing channel, particularly for small and financially constrained firms, whereas bank debt or term loans have no significant effect (Guney et al., 2017). Beyond firm-level financing mechanisms, the broader institutional environment also shapes the effects of R&D intensity. In BRICS countries R&D intensity reduces dividend payouts, but strong investor protection reverses the relationship, highlighting the importance of institutional factors (Hasan et al., 2022).

2.7.5 Lagged effects of R&D and the realization of innovation

The effects of R&D investment are often lagged and depend on the firm’s ability to convert inputs into innovation. He and Estébanez show that R&D improves the profitability of Chinese ICT SMEs both contemporaneously and with a lag, but reduces short-term liquidity. Market value responds in two stages: current R&D lowers Tobin’s Q, but after one or two years the effect becomes positive (He & Estébanez, 2023).

R&D expenditures predict future innovation in the chemical industry across all measures, and larger firms are more likely to innovate (Sun, 2015). In addition, R&D intensity carries information relevant for asset pricing: it effectively explains stock returns in Chinese firms, particularly the R&D/market value measure, which functions as an independent alpha source (Lu, 2020).

2.7.6 R&D intensity as a driver of competitiveness and market position

R&D investment strengthens firms' long-term competitiveness. Innovation improves the profitability of Vietnamese SMEs in both the short and long run, with effects transmitted through exports, productivity, access to credit, and public support (Mai et al., 2019). R&D intensity and returns to R&D capital are key drivers of profitability among the world's largest R&D investors (Rađenović et al., 2023). Market value increases particularly in firms operating at the technological frontier, where absorptive capacity is high, when R&D investment is strong (Andrade Rocha et al., 2019).

Not all R&D investment translates into profitability, however. In Korean venture firms R&D increases patenting but does not improve profitability, indicating that R&D can function as a strategic tool without immediate financial returns (Sohn et al., 2010).

2.7.7 R&D intensity from the perspective of sustainability and long-term value creation

R&D also supports the development of sustainable product attributes. In particular, R&D intensity improves both environmentally and socially sustainable product characteristics, and human capital strengthens this effect especially in the social dimension (Ullah & Arslan, 2022). In addition to these sustainability-related outcomes, R&D performance also has an economic dimension. The ROI^2 metric evaluates the economic effects of innovation by separating the net returns of innovation from its costs (Majka, 2024). Consistent with this perspective, prior research shows that R&D efficiency and production efficiency jointly explain firm market value, and that R&D outcomes translate into financial success only when they materialize as profitability and marketability (Wang et al., 2013).

2.8 Summary of the Literature Review

The overall picture emerging from the literature review shows that top management backgrounds, board structure, and corporate governance mechanisms influence firms' financial performance through complex, often context-dependent and non-linear causal pathways. No single managerial attribute—such as education, gender, tenure, or technical expertise—explains firm success on its own; rather, the effects arise from how these characteristics interact with board dynamics, ownership structure, monitoring mechanisms, and the firm's strategic environment.

First, findings on managerial education are highly heterogeneous. Elite education or an MBA degree do not systematically produce superior firm performance. Instead, certain fields of study—particularly finance, management, and business—may be associated with higher ROA and Tobin's Q in institutional environments where the labor-market value of education aligns well with firms' skill needs. Evidence from Indonesia and Nigeria supports this. At the same time, research shows that corporate-university backgrounds are consistently associated with weaker performance compared to degrees from independent universities, suggesting that firm-specific training produces less transferable and strategically relevant capabilities. Overall, the effect of education is clearly conditional and context-dependent.

Second, the role of the board chair is strategic and autonomous. The chair explains a substantial share of the variation in firm performance, particularly in complex and resource-constrained environments. Formal education, however, does not appear to be a consistent predictor of performance; instead, the chair's human capital, experience, interaction with the CEO, and ability to mobilize resources are more important.

Third, tenure affects firm outcomes in a non-linear manner. Early in a CEO's career, learning and accumulated experience improve performance, but with long tenure, entrenchment, risk aversion, and weakened monitoring turn the effect negative. The same pattern appears in boards: average tenure improves performance up to roughly ten years, after which it declines. Tenure diversity, in turn, enhances board effectiveness by balancing the advantages of short and long tenures.

Fourth, the effects of leadership turnover depend entirely on the nature of the turnover and the successor's background. Forced turnover can improve performance, particularly after competitive shocks, whereas voluntary turnover or successors misaligned with the firm's situation can weaken outcomes. Board renewal affects firm performance only when the change is sufficiently broad and includes the chair.

Fifth, the effect of gender on leadership is strongly context-dependent. A change in CEO gender weakens performance, but the decline is driven by the transition itself rather than by female leadership. Female leaders perform particularly well under certain conditions —such as in CEO-duality roles, in female-dominated organizations, or in low-equality countries—and are associated with positive market and profitability effects. Board gender composition can improve or weaken performance depending on firm size, context, and the actual influence of female directors.

Finally, R&D intensity is one of the most consistent drivers of firm performance, but its effects are highly conditional. R&D increases productivity, profits, market value, and long-term competitiveness, but also raises risk and requires sufficient absorptive capacity. Financing channels, the institutional environment, and the firm's technological capability determine the extent to which R&D investment translates into financial success.

Overall, the literature review shows that firm performance is not explained by any single managerial attribute or governance element, but by their interaction. Managerial backgrounds, board structure, ownership structure, gender composition, and R&D strategies form an interconnected system in which effects are often non-linear, context-dependent, and contingent on the firm's ability to deploy its resources strategically.

3 METHODOLOGY

3.1 Research Design

The study was conducted as a quantitative panel analysis examining the background characteristics of top executives and the financial performance of 27 Finnish publicly listed companies during 2014–2024. The panel is unbalanced because executive-level variables change in different years across firms, whereas financial variables are almost fully observed. The unit of analysis is the firm–year observation.

Using panel data enables the exploitation of both cross-sectional variation and temporal dynamics (Hsiao, 2007; Wooldridge, 2010, Chapter 7). The empirical analysis is structured around three model families:

1. Governance → R&D intensity
2. R&D intensity → ROI
3. Governance → Growth

All models were estimated using pooled OLS, and their diagnostic properties were evaluated using tests appropriate for dynamic panel models.

3.2 Sample Construction

3.2.1 Firm Selection Criteria

Firms were included in the study if they:

- appeared in the Talouselämä TE500 list during 2014–2024
- were Finnish publicly listed companies
- reported under IFRS standards

3.2.2 Impact of IFRS on R&D Figures

IFRS distinguishes between the research and development phases: research expenditures must always be expensed, whereas development expenditures may be capitalized if strict criteria are met. This distinction reduces the comparability of R&D intensity across firms (*IAS 38 Intangible Assets*, 2026).

3.3 Data Collection

Data were collected for an 11-year period (2014–2024), covering a total of 297 firm-year observations.

Financial variables were obtained from:

- annual reports (from 2014 to 2024)
- financial statements (from 2014 to 2024)
- Talouselämä TE500 publications (from 2015 to 2025) (Talouselämä, 2014)

Executive-level variables were collected from:

- annual reports (from 2014 to 2024)
- Corporate governance statements (from 2014 to 2024)
- stock exchange releases (from 2014 to 2024)

All required documents were retrieved for each year, and the information was manually extracted and tabulated. Current AI-based document-reading tools cannot reliably capture executive-level governance variables, making manual collection necessary. This process increased the total number of reports reviewed to nearly 1,000, which required substantial time and effort.

Collected financial variables included revenue, R&D spending, stock price (average and end-of-year), market capitalization, and return on investment (ROI). Governance variables included the CEO’s and Chair’s field(s) of education, education level, tenure, gender, age, and turnover. The aim was to collect these variables as comprehensively as possible for all years. The regression models ultimately used revenue, R&D spending, ROI, and governance variables for both the CEO and Chair: education field, education level, tenure, gender, and turnover.

To ensure that the dataset was complete, internally consistent, and correctly constructed, all variables underwent a structured data-level audit that examined missingness patterns, cross-source consistency, year-to-year continuity, and the correctness of variable construction. Full documentation of the data audit was reviewed as part of the internal assessment process but is not included in the public version of this thesis.

3.4 Executive Profile Description

Executive profiles were examined based on gender, field of education, education level, tenure, and turnover. The analysis covers all CEOs and Chairs of the 27 firms included in the study during 2014–2024.

3.4.1 Gender Distribution

The overwhelming majority of both CEOs and Chairs are men. Moreover, in this dataset, every individual who has at any point served in both roles—either simultaneously or at different times, and either within the same firm or across different firms—among the companies included in this study, is male. This gender imbalance requires careful interpretation of the gender variable, because the relative weight of individual female executives becomes disproportionately large, and firm-specific characteristics may influence statistical results (Table 1).

Table 1. Gender distribution in CEO and chair positions

Category	Count	Share of group (%)
CEO (Individuals)	75	100
CEO (Women)	8	10.7
CEO (Men)	67	89.3
Chair (Individuals)	60	100
Chair (Women)	3	5.0
Chair (Men)	57	95.0
CEO and Chair (Individuals)	11	100
CEO and Chair (Women)	0	0
CEO and Chair (Men)	11	100

3.4.2 Fields of Education

Fields of education were classified according to the theoretical framework, with business-related fields (Econ) serving as the reference category in the regression models (Hambrick, 2007; Hambrick & Mason, 1984). NSTE includes natural sciences, technology, and engineering. Juridic covers legal education. Other includes all remaining higher-education fields, and Multi refers to individuals with degrees from multiple fields (table 2).

Table 2. Distribution of educational fields in CEO and chair positions

Field	CEO (n=75)	CEO %	Chair (n=60)	Chair %	Both roles (n=11)	Both %
NSTE	36	48.0 %	21	35.0 %	8	72.7 %
Econ	27	36.0 %	24	40.0 %	2	18.2 %
Multi	9	12.0 %	7	11.7 %	0	0.0 %
Other	2	2.7 %	6	10.0 %	1	9.1 %
Juridic	1	1.3 %	2	3.3 %	0	0.0 %

3.4.3 Education Levels

Education level was defined based on the highest completed degree: 0 = no higher-education degree, 1 = bachelor's degree, 2 = master's degree, 3 = doctoral degree. If an individual held multiple degrees, classification was based on the highest one (Table 3).

Table 3. Distribution of educational levels in CEO and chair positions

Level	CEO (n=75)	CEO %	Chair (n=60)	Chair %	Both roles (n=11)	Both %
Bachelor	5	6.7	6	10.0	2	18.2
Master	61	81.3	47	78.3	9	81.8
Doctor	8	10.7	3	5.0	0	0.0
Other	1	1.3	4	6.7	0	0.0

3.4.4 Tenure

Tenure was defined annually as the number of years an individual had served as CEO or Chair. If an executive left and later returned, tenure was reset. Tenure varied substantially, with average tenure of 4.0 years for CEOs and 4.6 years for Chairs (Table 4).

Table 4. Average tenure in CEO and chair positions

Role	Min tenure	Max tenure	Average tenure
CEO	0	19	4.0
Chair	0	26	4.6

3.4.5 Turnover

Executive turnover was recorded for both CEOs and Chairs across the 11-year period. Total turnover was similar across roles: 63 CEO turnovers and 49 Chair turnovers, corresponding to an average of 2.33 (CEO) and 1.81 (Chair) turnovers per firm (Table 5).

Table 5. Turnover counts in the full dataset for CEO and chair positions

Metric	CEO Turnovers	Chair Turnovers
Total (297 observations)	63	49
Average per firm (11 years)	2.33	1.81

Turnover patterns show substantial heterogeneity: some firms experienced almost no turnover, while others saw exceptionally frequent changes. This variation is important for interpreting tenure and governance variables in the subsequent regression analysis (Table 6).

Table 6. Distribution of turnover cases per firm in CEO and chair positions

Turnovers per firm (CEO)	Firms (n)	Firms [%]	Turnovers per firm (Chair)	Firms (n)	Firms [%]
0	0	0.0	0	4	14.8
1	7	25.9	1	7	25.9
2	6	22.2	2	4	14.8
3	7	25.9	3	7	25.9
4	4	14.8	4	3	11.1
5	3	11.1	5	1	3.7

3.5 Variable Operationalization

3.5.1 Dependent Variables

R&D Intensity

$$RD\_Intensity = \frac{R\&D\ expenditure}{Revenue}$$

Equation 1. R&D intensity.

R&D intensity captures the relative scale of a firm's research and development investments compared to its revenue. It reflects how much the company allocates to building future competitiveness and innovation capacity in proportion to its current income stream. The variable is operationalized by dividing the firm's reported R&D expenditures by its net sales (Equation 1). This ratio is a widely used measure for comparing R&D commitment across firms of different sizes and for assessing the strategic importance of innovation-related investments in explaining long-term performance.

Full-sample distribution

To provide an overview of the full-sample distribution of R&D intensity, Table 7 reports the mean (RD_Intensity_avg), mean absolute deviation (RD_Intensity_MAD), and standard deviation (RD_Intensity_SD) calculated from all firm-year observations (N = 297). These statistics describe the overall level and variability of R&D intensity in the dataset and serve as a baseline for the regression analyses presented in Section 5. Firm-level calculations were reviewed during the internal assessment process but are not included in the public version of this thesis.

Table 7. Full-sample descriptive statistics for R&D intensity

Statistic	Value
RD_Intensity_avg (%)	2.80
RD_Intensity_MAD (%-points)	2.68

Statistic	Value
RD_Intensity_SD (%-points)	4.38

Return on Investment (ROI)

$$ROI = \frac{Net\ Income + Interest\ and\ Financial\ Expenses + Taxes}{Average\ Invested\ Capital}$$

Equation 2. Return on investment (ROI).

Return on Investment (ROI) measures a firm's ability to generate profits relative to the capital employed in its operations. In this study, ROI is calculated following the Talouselämä TE500 methodology (Equation 2). Invested capital is defined as total assets minus non-interest-bearing liabilities, including accounts payable, advances received, accruals, and other comparable items. This approach ensures a consistent and economically meaningful measure of the capital base, allowing ROI to capture how efficiently the firm converts invested resources into operating returns.

Revenue Growth (1-year, 3-year, 5-year)

$$Revenue\_growth\_kyr = \ln(Revenue_t) - \ln(Revenue_{t-k}) \quad , \quad (k \epsilon 1, 3, 5)$$

Equation 3. Revenue growth (1-year, 3-year, 5-year)

Revenue growth is measured using logarithmic growth rates rather than raw percentage changes (Equation 3). This approach is consistent with the structure of the underlying CSV matrix, which already contained log-transformed revenue values. The resulting measure corresponds to the continuous growth rate Δln, which is mathematically equivalent to percentage growth for small changes but offers superior statistical properties for regression modelling, particularly in terms of symmetry and scale invariance.

3.5.2 Governance Variables

Governance variables (Table 8) capture the annual characteristics of the Chief Executive Officer (CEO) and the Chair of the Board. All variables are coded directly from annual reports and Corporate Governance Statements.

Table 8. Executive-level governance variables

Variable	Description	Coding / Scale	Notes
CEO_Edu_Field	CEO’s field of education	Dummy-coded factor; reference = *Econ*	Categories: Econ, NSTE, Juridic, Other, Multi
CEO_Edu_Level	CEO’s highest degree	Ordinal (0–3)	0 = no degree, 1 = bachelor, 2 = master, 3 = doctorate
CEO_Gender	CEO gender	1 = female, 0 = male	—
CEO_Turnover	CEO turnover in a given year	1 = changed, 0 = unchanged	—
CEO_Tenure	Years in the role	Continuous	Resets if the executive leaves and later returns
Chair_Edu_Field	Chair’s field of education	Dummy-coded factor; reference = *Econ*	Same categories as CEO_Edu_Field
Chair_Edu_Level	Chair’s highest degree	Ordinal (0–3)	Same coding as CEO_Edu_Level
Chair_Gender	Chair gender	1 = female, 0 = male	—
Chair_Turnover	Chair turnover in a given year	1 = changed, 0 = unchanged	—
Chair_Tenure	Years in the role	Continuous	Resets if the executive leaves and later returns

3.5.3 Control Variables

Control variables (Table 9) vary across model families and follow exactly the specification implemented in the estimation code. Each model includes a set of theoretically and empirically justified controls to isolate the effect of the focal independent variables.

Table 9. Model families control variables

Model Family	Control Variables
Governance → RD_Intensity	ln_revenue; CEO/Chair tenure; CEO/Chair gender; CEO/Chair turnover; RD_{t-k}
RD_Intensity → ROI	ln_revenue; ROI_{t-1}
Governance → Revenue_growth	ln_revenue; CEO/Chair tenure; CEO/Chair gender; CEO/Chair turnover

Revenue growth variables are logarithmic growth rates imported directly from the data matrix. They are calculated as continuous log-differences, which provide a symmetric and regression-friendly measure of growth (Equation 4).

$$Growth_{kyr} = \ln(Revenue_t) - \ln(Revenue_{t-k}), \qquad k \in \{1, 3, 5\}$$

Equation 4. Calculation of logarithmic growth.

Control variables were selected based on theoretical relevance and their established role in prior empirical research. Firm size (ln_revenue) is included in all model families because it captures scale effects that influence both R&D investment levels and financial performance. Executive-level controls such as tenure, gender and turnover are included in the governance models to ensure that the estimated governance effects are not confounded by basic demographic or stability-related characteristics of firm leadership. In the R&D to ROI models, lagged ROI controls for persistence in firm-level profitability, allowing the coefficient on R&D intensity to reflect its incremental contribution to performance. In the governance to R&D models, lagged R&D intensity is included to account for the highly persistent nature of firms' innovation investment behaviour. These controls ensure that the estimated coefficients reflect the unique contribution of the focal explanatory variables rather than structural firm-level characteristics.

3.6 Model Specification

3.6.1 General OLS Model

The empirical analysis is based on the standard ordinary least squares (OLS) framework (Equation 5). The model relates the dependent variable y_{it} to a set of explanatory variables $x_{j,i,t}$, with coefficients β_j, an intercept α, and an idiosyncratic error term $\varepsilon_{i,t}$.

$$y_{i,t}=\alpha+\beta_1 x_{1,i,t}+\beta_2 x_{2,i,t}+\ \dots\ +\beta_k x_{k,i,t}+\varepsilon_{i,t}.$$

Equation 5. General OLS model.

Where:

- $y_{i,t}$ is the dependent variable for observation i at time t.
- $x_{j,i,t}$ are the explanatory variables.
- β_j are their coefficients.
- α is the intercept.
- $\varepsilon_{i,t}$ is the error term.

In matrix notation, the OLS estimator takes the familiar closed-form expression shown in Equation 6.

$$\hat{\beta}=(X^T X)^{-1} X^T y.$$

Equation 6. Ordinary least squares estimator.

In this formulation, X denotes the observation matrix of explanatory variables, y the vector of dependent-variable observations, and the estimated coefficient vector obtained from the OLS estimator.

The study distinguishes three coefficient groups for interpretative clarity:

- *β*-coefficients for main explanatory variables
- *γ*-coefficients for governance variables
- *δ*-coefficients for control variables

Mathematically, all of these are standard regression coefficients; the notation simply groups variables into conceptually coherent categories to support interpretation and model transparency.

3.6.2 Governance → RD

The relationship between governance characteristics and firms' R&D intensity is estimated using the regression specification shown in Equation 7. The model is estimated separately for different lag structures, where *k* ∈ {1,3,5}, capturing short-, medium-, and longer-term effects of governance variables on subsequent R&D investment levels.

$$RD\_Intensity_{i,t} = \alpha + \beta_1 RD\_Intensity_{i,t-k} + \beta_2 \ln(Revenue_{i,t}) + \gamma\, Governance_{i,t} + \sigma\, Controls_{i,t} + \varepsilon_{i,t}. \qquad , \qquad k \in \{1,3,5\}$$

Equation 7. Regression model for R&D intensity.

Explanation of Models M01–M12 (Governance → R&D Intensity)

Models M01–M12 focus on explaining why firms differ in their current level of R&D intensity. Because R&D intensity is a highly persistent characteristic—firms typically maintain similar R&D levels from year to year—the most informative way to analyse managerial influence is to relate governance characteristics to the firm's present R&D intensity while accounting for its established trajectory. For this reason, each model includes a lagged R&D-intensity term (one, three, or five years earlier), which captures the firm's long-standing innovation behaviour.

The lagged term ensures that the analysis does not simply compare firms that have always differed in their R&D strategies. Instead, the models examine whether managerial backgrounds are associated with deviations from what the firm's own history would predict. This approach isolates the incremental contribution of governance characteristics by holding constant the structural and persistent elements of R&D behaviour.

Each specification introduces one governance variable at a time—either the CEO's or the Chair's field of education or level of education—allowing the models to assess whether particular educational backgrounds are linked to systematically higher or lower R&D intensity. Controls for firm size, tenure, gender, and turnover ensure that the estimated associations are not driven by basic demographic or structural differences in leadership.

Together, these models provide a clear and methodologically appropriate way to address the first research question: whether managerial characteristics are associated with the level of R&D intensity that firms exhibit once their historical R&D trajectory is taken into account. The full model structure is presented in Table 10.

Table 10. Governance → R&D intensity (Models M01–M12)

Model	Dependent Variable	Governance Variable	Controls
M01	RD_Intensity_t	CEO_Edu_Field	RD_Intensity_t_minus1, ln_Revenue, CEO_Tenure, CEO_Gender_Female_1_Male_0, CEO_Turnover_0_or_1
M02	RD_Intensity_t	CEO_Edu_Field	RD_Intensity_t_minus3, ln_Revenue, CEO_Tenure, CEO_Gender_Female_1_Male_0, CEO_Turnover_0_or_1
M03	RD_Intensity_t	CEO_Edu_Field	RD_Intensity_t_minus5, ln_Revenue, CEO_Tenure, CEO_Gender_Female_1_Male_0, CEO_Turnover_0_or_1
M04	RD_Intensity_t	CEO_Edu_Level	RD_Intensity_t_minus1, ln_Revenue, CEO_Tenure, CEO_Gender_Female_1_Male_0, CEO_Turnover_0_or_1
M05	RD_Intensity_t	CEO_Edu_Level	RD_Intensity_t_minus3, ln_Revenue, CEO_Tenure, CEO_Gender_Female_1_Male_0, CEO_Turnover_0_or_1
M06	RD_Intensity_t	CEO_Edu_Level	RD_Intensity_t_minus5, ln_Revenue, CEO_Tenure, CEO_Gender_Female_1_Male_0, CEO_Turnover_0_or_1
M07	RD_Intensity_t	Chair_Edu_Field	RD_Intensity_t_minus1, ln_Revenue, Chair_Tenure, Chair_Gender_Female_1_Male_0, Chair_Turnover_0_or_1
M08	RD_Intensity_t	Chair_Edu_Field	RD_Intensity_t_minus3, ln_Revenue, Chair_Tenure, Chair_Gender_Female_1_Male_0, Chair_Turnover_0_or_1
M09	RD_Intensity_t	Chair_Edu_Field	RD_Intensity_t_minus5, ln_Revenue, Chair_Tenure, Chair_Gender_Female_1_Male_0, Chair_Turnover_0_or_1
M10	RD_Intensity_t	Chair_Edu_Level	RD_Intensity_t_minus1, ln_Revenue, Chair_Tenure, Chair_Gender_Female_1_Male_0, Chair_Turnover_0_or_1
M11	RD_Intensity_t	Chair_Edu_Level	RD_Intensity_t_minus3, ln_Revenue, Chair_Tenure, Chair_Gender_Female_1_Male_0, Chair_Turnover_0_or_1
M12	RD_Intensity_t	Chair_Edu_Level	RD_Intensity_t_minus5, ln_Revenue, Chair_Tenure, Chair_Gender_Female_1_Male_0, Chair_Turnover_0_or_1

3.6.3 RD → ROI

The impact of firms’ R&D intensity on subsequent return on investment (ROI) is estimated using the regression specification presented in Equation 8. The model evaluates whether higher levels of R&D investment translate into improved financial performance in the following period, after controlling for firm size and prior profitability. By including lagged ROI, the specification accounts for persistence in firm-level performance, allowing the coefficient on R&D intensity to capture its incremental contribution to operational returns.

$$ROI_{i,t} = \alpha + \beta_1 RD\_Intensity_{i,t-k} + \beta_2 ROI_{i,t-1} + \beta_3 \ln(Revenue_{i,t}) + \varepsilon_{i,t} \quad , \quad k \in \{1,3,5\}$$

Equation 8. Regression model for ROI.

Explanation of Models M13–M15 (R&D Intensity → ROI)

Models M13–M15 examine whether earlier R&D investments are reflected in firms’ current profitability. Because the economic effects of R&D materialise gradually—development cycles are long, outcomes uncertain, and commercialisation delayed—the models relate current-year ROI to R&D intensity measured one, three, or five years earlier. Table 11 summarises the structure of these specifications.

Table 11. R&D intensity → ROI (Models M13–M15)

Model	Dependent Variable	Key Predictor (RD Lag)	Controls
M13	ROI	RD_Intensity_t_minus1	ln_Revenue, ROI_t_minus1
M14	ROI	RD_Intensity_t_minus3	ln_Revenue, ROI_t_minus1
M15	ROI	RD_Intensity_t_minus5	ln_Revenue, ROI_t_minus1

Using lagged R&D intensity serves two methodological purposes. It reflects the theoretical expectation that R&D affects profitability only after a delay, and it avoids simultaneity problems that would arise if current R&D intensity were used to explain current profitability. By ensuring that the explanatory variable precedes the outcome, the models provide a cleaner interpretation of the association between R&D activity and subsequent financial performance.

To account for the persistence of profitability, each model includes lagged ROI as a control variable. Firms with structurally high or low ROI tend to maintain those patterns, and controlling for past profitability ensures that the estimated effect of R&D intensity is not confounded by long-standing firm-specific characteristics. Firm size is included for similar reasons, as larger firms often exhibit more stable profit structures.

These elements together form a coherent framework for assessing how earlier R&D intensity relates to current profitability. The models do not aim to establish strict causality, but they offer a rigorous way to evaluate whether development-oriented or research-oriented R&D strategies are associated with stronger or weaker economic outcomes. Full specifications are presented in Table 11.

3.6.4 Governance → Growth

The effect of governance characteristics on firm growth is estimated using the regression specification shown in Equation 9. The model evaluates whether board- and executive-level attributes are associated with subsequent revenue expansion once firm size and leadership demographics are taken into account.

Growth is operationalised using continuous logarithmic revenue differences, which offer a scale-invariant and regression-friendly measure of firm-level expansion.

$$Growth_{i,t} = \alpha + \beta_1 \ln(Revenue_{i,t}) + \gamma \, Governance_{i,t} + \sigma \, Controls_{i,t} + \varepsilon_{i,t}.$$

Equation 9. Regression model for firm growth.

Firm growth is defined as the log-difference in revenue over horizons of one, three, and five years (Equation 10):

$$Growth_{i,t} = \ln(Revenue_{i,t}) - \ln(Revenue_{i,t-k}) \quad , \quad k \in \{1,3,5\}$$

Equation 10. Definition of growth.

Explanation of Models M16–M27 (Governance → Revenue Growth)

Models M16–M27 analyse whether managerial educational backgrounds are associated with firms' revenue growth over one-, three-, and five-year horizons. These models link governance characteristics measured in year t to growth observed in subsequent periods, reflecting the idea that growth accumulates over time through strategic decisions and market conditions. Tables 12–14 present the full structure of the models for each horizon.

Unlike R&D intensity or profitability, revenue growth does not exhibit year-to-year persistence. Growth rates fluctuate substantially due to market dynamics, competitive shifts, and firm-specific events, and past growth does not reliably predict future growth. For this reason, lagged growth is not included as a control variable. Instead, the models focus on whether managerial characteristics are associated with systematically different growth outcomes once firm size and basic leadership demographics are taken into account. Firm size is included because larger firms typically grow more slowly in percentage terms.

The governance variables capture two dimensions of managerial human capital: educational field and educational level. Separate models for CEOs and Chairs recognise that these roles may influence strategic direction in different ways. The one-year models capture short-term responsiveness to managerial characteristics, while the three- and five-year models reflect medium- and longer-term strategic effects.

Taken together, these models provide a structured and theoretically grounded way to address the second research question: whether managerial human capital is associated with firms' revenue growth over different time horizons. The multi-horizon design allows the analysis to distinguish between immediate and more persistent growth dynamics. Detailed specifications are presented in Tables 12–14.

Table 12. One-year revenue growth (Models M16–M19)

Model	Dependent Variable	Governance Variable	Controls
M16	Revenue_Growth_1yr	CEO_Edu_Field	ln_Revenue, CEO_Tenure, CEO_Gender_Female_1_Male_0, CEO_Turnover_0_or_1
M17	Revenue_Growth_1yr	CEO_Edu_Level	ln_Revenue, CEO_Tenure, CEO_Gender_Female_1_Male_0, CEO_Turnover_0_or_1
M18	Revenue_Growth_1yr	Chair_Edu_Field	ln_Revenue, Chair_Tenure, Chair_Gender_Female_1_Male_0, Chair_Turnover_0_or_1
M19	Revenue_Growth_1yr	Chair_Edu_Level	ln_Revenue, Chair_Tenure, Chair_Gender_Female_1_Male_0, Chair_Turnover_0_or_1

Table 13. Three-year revenue growth (Models M20–M23)

Model	Dependent Variable	Governance Variable	Controls
M20	Revenue_Growth_3yr	CEO_Edu_Field	ln_Revenue, CEO_Tenure, CEO_Gender_Female_1_Male_0, CEO_Turnover_0_or_1
M21	Revenue_Growth_3yr	CEO_Edu_Level	ln_Revenue, CEO_Tenure, CEO_Gender_Female_1_Male_0, CEO_Turnover_0_or_1
M22	Revenue_Growth_3yr	Chair_Edu_Field	ln_Revenue, Chair_Tenure, Chair_Gender_Female_1_Male_0, Chair_Turnover_0_or_1
M23	Revenue_Growth_3yr	Chair_Edu_Level	ln_Revenue, Chair_Tenure, Chair_Gender_Female_1_Male_0, Chair_Turnover_0_or_1

Table 14. Five-year revenue growth (Models M24–M27)

Model	Dependent Variable	Governance Variable	Controls
M24	Revenue_Growth_5yr	CEO_Edu_Field	ln_Revenue, CEO_Tenure, CEO_Gender_Female_1_Male_0, CEO_Turnover_0_or_1
M25	Revenue_Growth_5yr	CEO_Edu_Level	ln_Revenue, CEO_Tenure, CEO_Gender_Female_1_Male_0, CEO_Turnover_0_or_1
M26	Revenue_Growth_5yr	Chair_Edu_Field	ln_Revenue, Chair_Tenure, Chair_Gender_Female_1_Male_0, Chair_Turnover_0_or_1
M27	Revenue_Growth_5yr	Chair_Edu_Level	ln_Revenue, Chair_Tenure, Chair_Gender_Female_1_Male_0, Chair_Turnover_0_or_1

3.7 Estimation Method

3.7.1 Pooled OLS

Pooled OLS was selected for three reasons:

1. Governance variables are nearly time-invariant at the firm level.
2. Mixed-model variance components indicate no firm-specific random effects.
3. The Hausman test shows that FE and RE produce systematically different estimates.

In practice, pooled OLS is the only estimator capable of identifying governance effects reliably, because governance variables do not vary within firms, FE cannot estimate them, and RE is biased. Mixed-model variance components further confirmed the absence of random effects. Driscoll–Kraay robust standard errors were used to correct for heteroskedasticity and cross-sectional dependence (Wooldridge, 2010, Chapter 7).

All statistical analyses were conducted in R (version 4.5.1) using the packages *dplyr, tidyr, tibble, purrr, ggplot2, patchwork, broom, car, lmtest, plm, lme4, sandwich, openxlsx and base64enc*. The entire regression pipeline, including data audit, model audit and results audit, was executed using these packages within a fully scripted and reproducible workflow.

3.7.2 Robust Standard Errors and Driscoll–Kraay

Panel datasets typically exhibit heteroskedasticity, autocorrelation, and cross-sectional dependence. For this reason, the study employed Driscoll–Kraay robust standard errors. In this study, Driscoll–Kraay standard errors provided a reliable way to correct the most common issues in panel data, because they are robust to heteroskedasticity, within-unit autocorrelation, and cross-sectional dependence across firms. This made them particularly suitable for the pooled OLS model, which does not include firm-specific fixed or random effects but in which structural dependencies in the error terms could otherwise distort conventional standard errors. The Driscoll–Kraay correction ensured that statistical significance was based on a realistic error structure and that the conclusions were not driven by overly optimistic or biased standard errors (Driscoll & Kraay, 1998; Wooldridge, 2010, Chapter 7).

3.8 Diagnostics

3.8.1 Panel Autocorrelation

The Wooldridge test (Wooldridge, 2010, Ch. 7) is the standard method for detecting first-order autocorrelation in panel datasets, and it is based on regressing the model's residuals on their lagged values. The test is particularly useful because it does not require a balanced panel or a large number of observations, and it performs reliably even when the panel contains only a few time periods. The test result indicates whether the model's error term exhibits systematic within-unit temporal dependence, which can distort standard errors and lead to incorrect inferences. In this study, the Wooldridge test indicated the presence of autocorrelation in the panel data, which reinforced the need to use Driscoll–Kraay robust standard errors, as they correct for autocorrelation as well as other typical error-structure issues in panel datasets (Wooldridge, 2010, Chapter 7).

3.8.2 Cross-Sectional Dependence

Pesaran's CD test (Pesaran, 2004) and the Breusch–Pagan LM test (Breusch & Pagan, 1980) are key tools for detecting cross-sectional dependence in panel datasets—that is, situations in which the error terms of different firms are correlated with each other. This is typical in economic panels, where firms operate in the same markets and are exposed to similar macroeconomic shocks. Both tests indicated significant cross-sectional dependence in the data, which made conventional OLS standard errors unreliable. For this reason, the study employed Driscoll–Kraay robust standard errors, which specifically correct for cross-sectional dependence and ensure that statistical conclusions are not based on underestimated standard errors (Wooldridge, 2010, Chapter 7).

3.8.3 Assessment of Random Effects

The assessment of random effects is based on determining whether there is systematic variation in firm-specific error components that should be modelled as a separate random effect. The Breusch–Pagan LM test (Breusch & Pagan, 1980) evaluates whether the variance of the random effects is statistically significant; if it is not, the RE model provides no added value. The Hausman test (Hausman, 1978) compares FE and RE estimates and tests whether the random effects are uncorrelated with the regressors—if correlation exists, the RE model is biased. Mixed-model variance component analysis (Bates et al., 2015) complements the assessment by directly estimating the magnitude of the random effects. In this study, all three methods consistently indicated that firm-specific random effects were absent and that the assumptions of the RE model were not met. Consequently, pooled OLS remained the only estimation method that produced both theoretically and empirically justified estimates (Wooldridge, 2010, Chapter 7).

3.8.4 Multicollinearity

Variance Inflation Factors (VIFs) are a well-established method for assessing multicollinearity—that is, excessive correlation among explanatory variables (O'brien, 2007). High multicollinearity can inflate standard errors, reduce the precision of estimates, and make the interpretation of individual variable effects unreliable. VIFs measure how much the variance of each variable increases due to linear dependence with other regressors. In this study, VIF values were clearly below commonly used thresholds (5 or 10), indicating that the models did not suffer from problematic multicollinearity. As a result, the estimates are stable, and the effects of governance variables can be interpreted without concerns about excessive overlap among the explanatory variables (Wooldridge, 2010, Chapter 7).

3.9 Model Execution and Reporting

The entire regression pipeline was implemented as a modular and automated analysis chain consisting of four main stages: model generation and estimation, data audit, model audit, and results audit and reporting. All stages were integrated into a single workflow that enables the analysis to be executed reproducibly in one run.

To ensure that the estimated models were correctly specified and that their structural assumptions were met, each model underwent a dedicated model-level diagnostic audit. This audit includes checks of model specification, variance-component structure, baseline residual behaviour, and the consistency of fixed- and random-effects formulations. All model-level diagnostics were reviewed as part of the internal assessment process but are not included in the public version of this thesis.

3.10 Summary of Methodological Choices

The methodology is grounded in:

- panel-data techniques
- pooled OLS estimation
- Driscoll–Kraay robust standard errors
- diagnostics suitable for dynamic panels
- multicollinearity assessment
- random-effects evaluation
- upper-echelons governance theory
- empirical literature on firm growth

4 EXPLORATORY DATA ANALYSIS

The purpose of the exploratory data analysis (EDA) is to establish a comprehensive understanding of the structure of the dataset before estimating the regression models. This chapter examines the distributions of the key economic variables, their temporal behaviour, and the relationships between governance variables and R&D intensity. EDA therefore provides both the methodological foundation and the interpretative framework for the subsequent empirical analysis.

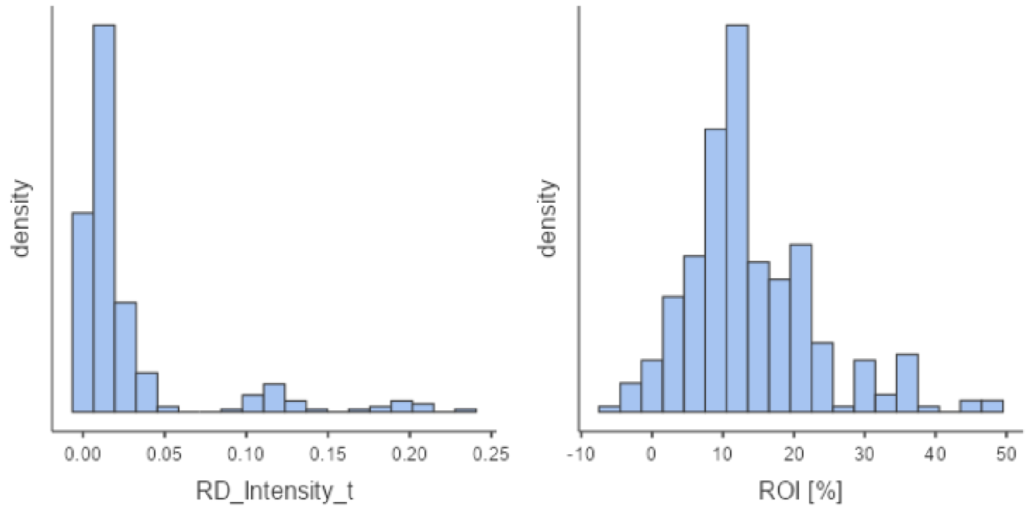
4.1 Distributions of R&D Intensity and ROI

A natural starting point for the analysis is to examine the distributions of the core economic variables. R&D intensity (RD_Intensity_t) and profitability (ROI) are central to the study, and the shape of their distributions directly influences modelling choices. Skewness, dispersion, and the presence of extreme values determine which estimation techniques are appropriate and how results should be interpreted.

The distribution of R&D intensity, shown in Figure 1, is markedly right-skewed. Most firms operate at very low levels of R&D intensity, while only a small subset invests heavily. This is reflected in the substantial gap between the median (0.0131) and the mean (0.0280). The long right tail is economically intuitive: R&D expenditures tend to be concentrated among a limited number of firms, a pattern well documented in the international literature.

In contrast, the distribution of ROI (also in Figure 1) is considerably more symmetric and approximates a normal distribution. Most observations fall between 0% and 25%, and the proximity of the median (12%) and mean (13.9%) supports the impression of balance. The standard deviation (9.29), however, indicates substantial variation in profitability across firms.

Figure 1. Density distributions of RD_Intensity_t (left) and ROI (right)



The key descriptive statistics are summarised in Table 15, which reinforces the visual impressions. The pronounced skewness of R&D intensity and the broad yet balanced distribution of ROI form the basis for later modelling decisions. The skewness of RD_Intensity_t helps explain the behaviour of the dynamic regressions, while the distribution of ROI supports the use of linear modelling techniques.

Table 15. Descriptive statistics for RD_Intensity_t and ROI

Statistic	RD_Intensity_t	ROI
N	297	296
Missing	0	1
Mean	0.0280	13.9
Median	0.0131	12.0
Standard deviation	0.0438	9.29
Minimum	0.000543	–5.00
Maximum	0.235	49.0

4.2 Autocorrelation of R&D Intensity

The temporal persistence of R&D intensity is one of the most striking structural features of the dataset. R&D expenditures are inherently strategic and long-term: they reflect a firm’s technological trajectory, competitive position, and industry-specific innovation dynamics. Consequently, R&D intensity is expected to evolve slowly rather than reactively, making it essential to document the degree of persistence before estimating dynamic models.

Figure 2 plots RD_Intensity_t against RD_Intensity_t-1. The scatterplot reveals an almost perfectly linear relationship: observations cluster tightly around an upward-sloping diagonal, and the fitted line follows the data with minimal deviation. This visual pattern suggests that a firm's current R&D intensity is highly predictable based on its previous year's level.

Figure 2. Autocorrelation between RD_Intensity_t-1 and RD_Intensity_t

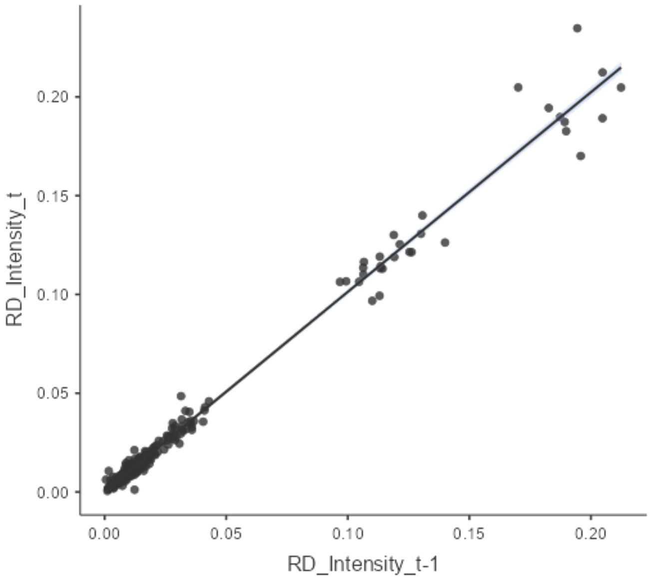


Table 16 confirms this impression. The Pearson correlation coefficient is exceptionally high ($r = 0.993$, $p < .001$, $df = 268$), indicating a near-deterministic relationship. Year-to-year variation in R&D intensity is minimal, and the variable behaves almost as a fixed characteristic of the firm.

Table 16. Correlation matrix: RD_Intensity_t-1 and RD_Intensity_t

	RD_Intensity_t-1	RD_Intensity_t
RD_Intensity_t-1	—	0.993
df	—	268
p-value	—	< .001
RD_Intensity_t	0.993	—
df	268	—
p-value	< .001	—

This level of persistence is economically plausible. R&D programmes are rarely short-term decisions; they are embedded in multi-year strategic commitments, contractual arrangements, and resource allocations. The methodological implications are substantial. First, the near-unit coefficients observed in later regressions ($\beta \approx 1$) are not artefacts but reflect the underlying structure of the data. Second, the dominance of RD_Intensity_t-1 mechanically limits the explanatory power of governance variables. Third, the strong autocorrelation implies serial dependence in the error terms, making Driscoll–Kraay standard errors not merely advisable but necessary.

In summary, R&D intensity is an extremely persistent variable, consistent with international evidence. This persistence underpins the behaviour of the dynamic models and explains why governance variables exhibit limited explanatory power.

4.3 Autocorrelation of ROI

The temporal behaviour of ROI provides a complementary perspective on firm performance. Profitability reflects competitive position, market conditions, and strategic decisions—factors that typically evolve gradually. ROI is therefore expected to be persistent, though not to the same extent as R&D intensity, which is shaped by even longer-term strategic planning.

Figure 3 plots ROI_t against ROI_t-1. The scatterplot shows a clear upward trend: firms with high profitability in the previous year tend to remain profitable, and the fitted line passes smoothly through the centre of the point cloud. The pattern indicates strong persistence, albeit with more year-to-year variation than in R&D intensity.

Figure 3. Autocorrelation between ROI_t-1 and ROI_t

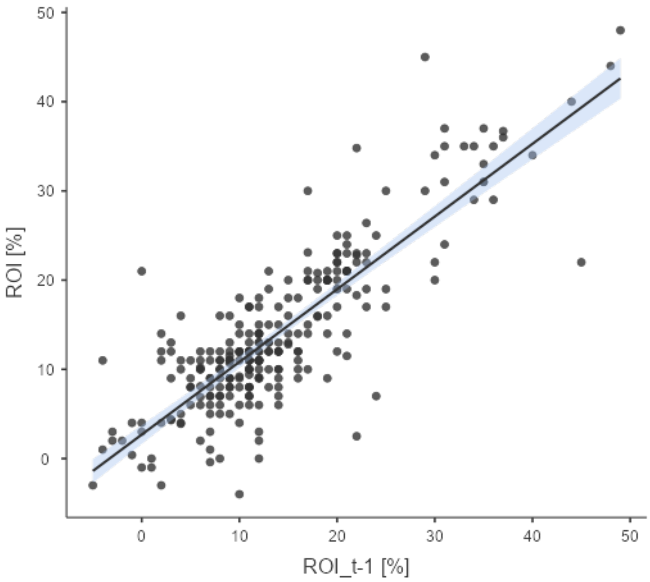


Table 17 quantifies this relationship. The Pearson correlation coefficient is r = 0.845 (p < .001, df = 267), a very high value in economic data. Unlike R&D intensity, ROI is not nearly deterministic, but it is clearly anchored to its historical level.

Table 17. Correlation matrix: ROI_t-1 and ROI_t

	ROI_t-1	ROI_t
ROI_t-1 [%]	—	0.845
df	—	267
p-value	—	< .001
ROI [%]	0.845	—
df	267	—
p-value	< .001	—

The persistence of ROI is economically intuitive. Profitability reflects competitive advantages, cost structures, and market positioning—factors that do not shift abruptly. This structure supports the inclusion of ROI_t-1 as a control variable in the R&D → ROI models. As with R&D intensity, the autocorrelation implies serial dependence in the error terms, reinforcing the need for Driscoll–Kraay corrections.

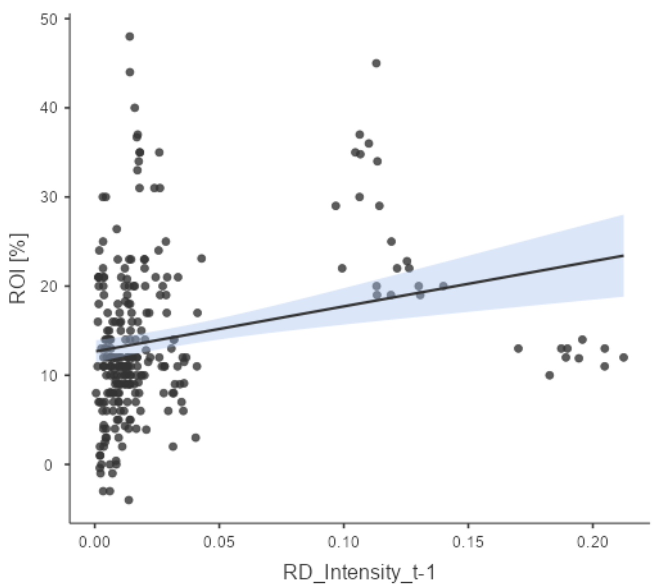
In summary, ROI is strongly—but not perfectly—persistent. This persistence helps explain why changes in R&D intensity can produce statistically significant effects on profitability: when the dependent variable is relatively stable, even modest changes in the explanatory variable can generate detectable signals.

4.4 Relationship Between RD_Intensity_t-1 and ROI

The relationship between R&D intensity and profitability is central to the theoretical framework of this study. Although the literature documents a positive association between R&D investment and firm performance, the magnitude of the effect varies across industries and over time. This section examines the extent to which lagged R&D intensity (RD_Intensity_t-1) explains current profitability (ROI_t).

Figure 4 plots RD_Intensity_t-1 against ROI. The scatterplot reveals a weak but consistent positive trend: firms that invest more heavily in R&D tend to achieve slightly higher profitability. The fitted regression line and its 95% confidence interval reinforce this impression. The point cloud is, however, far more dispersed than in the R&D autocorrelation plot, indicating that R&D intensity is only one of many factors influencing profitability.

Figure 4. Scatter plot of RD_Intensity_t-1 and ROI [%]



Model fit statistics are presented in Table 18, and the regression coefficients in Table 19. The model explains a modest share of the variation in ROI (R^2 = 0.0595), which is typical in economic settings where profitability is influenced by numerous firm-specific and market-specific factors. Nevertheless, the coefficient on RD_Intensity_t-1 is positive and statistically significant ($\beta = 50.7$, $p < .001$), indicating a systematic—albeit limited—relationship.

Table 18. Model fit measures

Model	R	R^2
1	0.244	0.0595

N = 269

Table 19. Model coefficients – ROI [%]

Predictor	Estimate	SE	t	p
Intercept	12.7	0.632	20.03	< .001
RD_Intensity_t-1	50.7	12.323	4.11	< .001

N = 269

Economically, the result is intuitive. R&D investments are long-term commitments whose benefits often materialise with a delay. It is therefore expected that RD_Intensity_t-1 explains only part of ROI_t. Moreover, ROI is itself highly persistent ($r = 0.845$), meaning that much of its variation is driven by the firm's own historical trajectory rather than external predictors. As a result, the effect of R&D intensity appears as a clear but relatively small signal in the regressions.

In summary, R&D intensity has a statistically significant and economically plausible effect on profitability, though the magnitude is modest compared to the influence of ROI's own persistence. This finding aligns with the broader literature: R&D supports profitability, but it does not determine it.

4.5 CEO Education Level and R&D Intensity

The relationship between the CEO's level of education and the firm's R&D intensity provides an initial perspective on how managerial human capital may shape innovation-related investment decisions. Education level is an ordinal variable that reflects the depth of formal training and, potentially, the CEO's ability to understand and support long-term technological initiatives. It is therefore reasonable to examine whether education level is associated with R&D intensity prior to estimating the regression models.

Figure 5 plots CEO_Edu_Level against RD_Intensity_t. The scatterplot reveals a weak but consistent positive trend: higher education levels are associated with slightly higher R&D intensity. The observations cluster distinctly by education category, as expected for an ordinal variable, and the fitted regression line slopes gently upward. The pattern is smooth and monotonic, with no indication of non-linearity or influential outliers.

Figure 5. Scatter plot of CEO_Edu_Level and RD_Intensity_t

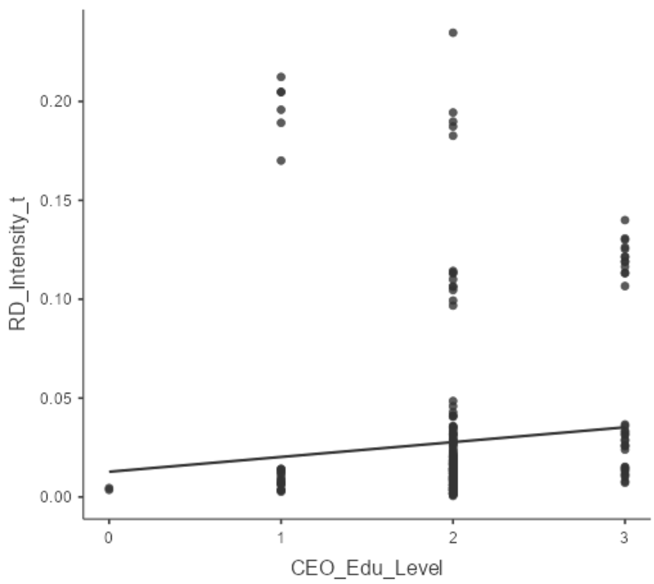


Table 20 confirms the visual impression. The Spearman correlation coefficient is ρ = 0.266 ($p < .001$, N = 297), indicating a weak but statistically robust positive association. Given the ordinal nature of the education variable, Spearman's rho is the appropriate measure.

Table 20. Correlation matrix (Spearman): CEO_Edu_Level and RD_Intensity_t

	RD_Intensity_t	CEO_Edu_Level
RD_Intensity_t	—	0.266
df	—	295
p-value	—	< .001
CEO_Edu_Level	0.266	—
df	295	—
p-value	< .001	—

Economically, the result is intuitive. Higher education may enhance a CEO’s ability to evaluate the long-term benefits of technological investment, understand the strategic role of R&D, or foster an innovation-oriented organisational culture. Although the effect is modest, it is systematic and statistically significant, suggesting that education level contributes to explaining cross-firm differences in R&D intensity.

Methodologically, the result supports the inclusion of governance variables in the regression models. While the effect of education level is small relative to the overwhelming persistence of R&D intensity itself ($r = 0.993$), it nonetheless provides incremental explanatory power that RD_Intensity_t-1 alone cannot capture. This is particularly relevant in dynamic models where most variation is absorbed by the lagged dependent variable.

In summary, CEO education level is weakly but consistently associated with R&D intensity. The relationship is statistically significant and economically plausible, supporting its role as a governance variable in subsequent models.

4.6 Chair Education Level and R&D Intensity

The relationship between the chair’s level of education and the firm’s R&D intensity offers a complementary perspective on governance. Unlike the CEO, the chair does not make operational decisions regarding R&D investments but influences strategic oversight and board-level direction. It is therefore reasonable to examine whether education level is associated with R&D intensity, even if a weaker relationship is expected.

Figure 6 plots Chair_Edu_Level against RD_Intensity_t. The scatterplot shows no discernible trend: observations form a diffuse cloud without upward or downward structure, and the fitted line is essentially flat. There is no visible clustering by education level, nor any indication of non-linearity or outliers that would distort interpretation.

Figure 6. Scatter plot of Chair_Edu_Level and RD_Intensity_t

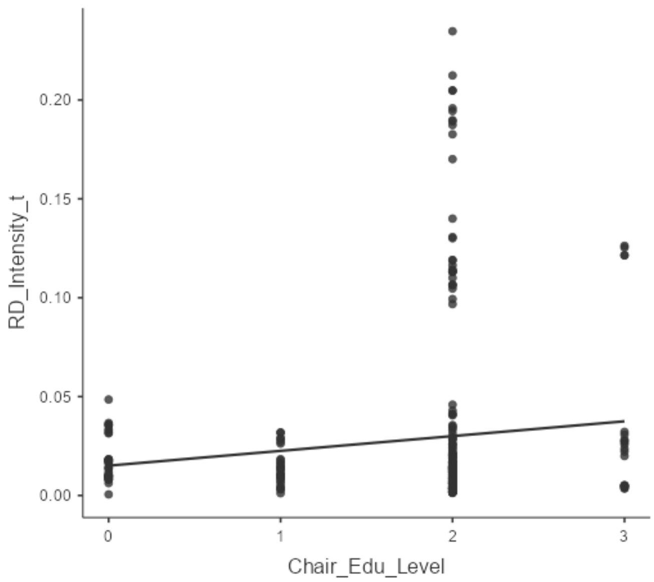


Table 21 confirms the absence of association. The Spearman correlation coefficient is ρ = –0.005 (p = 0.931, N = 297), effectively zero and far from statistical significance.

Table 21. Correlation matrix (Spearman): Chair_Edu_Level and RD_Intensity_t

	RD_Intensity_t	Chair_Edu_Level
RD_Intensity_t	—	–0.005
df	—	295
p-value	—	0.931
Chair_Edu_Level	–0.005	—
df	295	—
p-value	0.931	—

This result is economically consistent with the chair's role. As a strategic overseer rather than an operational decision-maker, the chair's education level is unlikely to directly influence annual R&D spending. The contrast with the CEO's education level—which showed a weak but systematic association—highlights the difference between strategic oversight and day-to-day managerial decision-making.

Methodologically, the finding indicates that Chair_Edu_Level does not contribute meaningful explanatory power to cross-firm variation in R&D intensity. Its effect is negligible and indirect, and it is not a central governance variable for the subsequent regression models.

In summary, chair education level is not associated with R&D intensity. The relationship is statistically insignificant and economically weak, reinforcing the view that the chair's educational background is not an informative indicator of a firm's innovation orientation.

4.7 CEO Education Field and R&D Intensity

The CEO's field of education provides a more nuanced perspective on managerial human capital. Unlike education level, which captures the depth of formal training, education field reflects the type of knowledge and expertise the CEO brings to strategic decision-making. It is therefore relevant to examine whether firms' R&D intensities differ systematically across educational backgrounds such as Natural Science and Technology (NSTE), economics, law, multidisciplinary, or other fields.

Figure 7 presents the distribution of RD_Intensity_t across education fields. The boxplots reveal pronounced differences: CEOs with Natural Science and Technology (NSTE) or multidisciplinary (Multi) backgrounds lead firms with higher and more dispersed R&D intensities. CEOs with economics training (Econ) fall between these groups, while those in the "Other" and legal (Juridic) categories exhibit very low R&D intensities with minimal variation.

Figure 7. RD_Intensity_t by CEO_Edu_Field

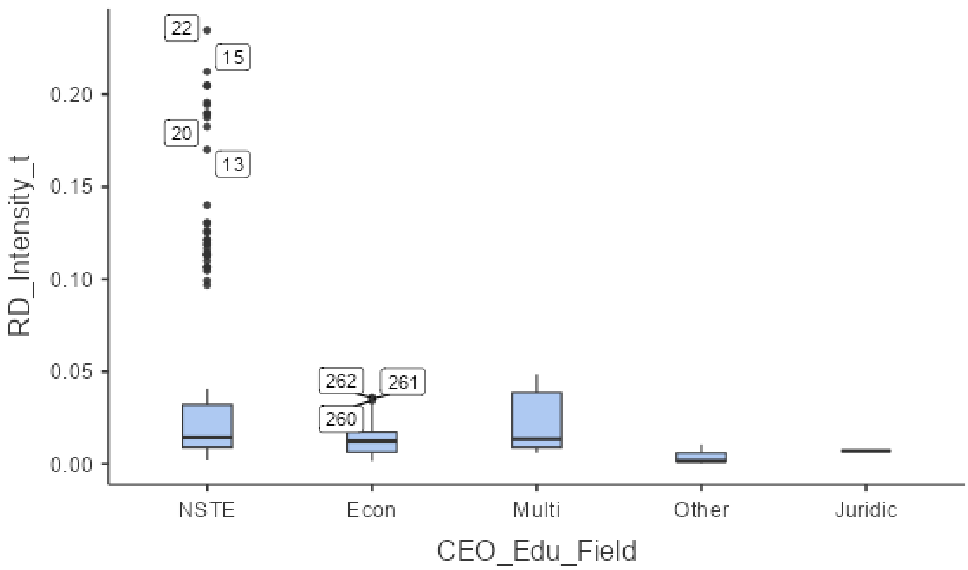


Table 22 reinforces these visual differences. The Kruskal–Wallis test indicates a highly significant difference across groups ($\chi^2 = 37.4$, $p < .001$), with an effect size of $\varepsilon^2 = 0.126$. This medium-sized effect implies that education field explains approximately 12.6% of the variation in R&D intensity—substantial given the strong persistence of the variable.

Table 22. Kruskal–Wallis test for RD_Intensity_t by CEO_Edu_Field

	χ^2	df	p	ε^2
RD_Intensity_t	37.4	4	< .001	0.126

Pairwise comparisons were conducted using the Dwass–Steel–Critchlow–Fligner (DSCF) procedure, a non-parametric multiple-comparison method appropriate after a Kruskal–Wallis test. Pairwise comparisons (Table 23) show that the most pronounced differences involve the “Other” category: NSTE vs Other, Econ vs Other, and Multi vs Other are all highly significant. This indicates that CEOs with heterogeneous or non-technical backgrounds lead firms with systematically lower R&D intensities.

Table 23. Pairwise comparisons (DSCF)

Group 1	Group 2	W	p
NSTE	Econ	-4.613	0.010
NSTE	Multi	-0.113	1.000
NSTE	Other	-7.260	< .001
NSTE	Juridic	-1.455	0.842
Econ	Multi	2.530	0.380
Econ	Other	-6.544	< .001
Econ	Juridic	-1.067	0.943
Multi	Other	-5.856	< .001
Multi	Juridic	-1.807	0.705
Other	Juridic	1.309	0.887

Economically, the results are coherent. CEOs with technical or multidisciplinary training may better understand the strategic value of R&D and be more inclined to support innovation-oriented investments. Economics-trained CEOs occupy an intermediate position, consistent with their ability to evaluate financial implications but not necessarily technological depth. The low R&D intensity in the “Other” category reflects the heterogeneity of backgrounds with limited relevance to innovation.

Methodologically, the findings are important. Unlike education level, which explains only a small share of variation, education field accounts for a meaningful portion of cross-firm differences in R&D intensity. This makes it one of the most informative governance variables in the dataset and helps explain why governance effects in the regressions appear only in specific subgroups: the relationship is not linear but categorical.

In summary, CEO education field is a significant determinant of R&D intensity. The differences across groups are clear, statistically strong, and economically plausible, underscoring the relevance of managerial expertise for innovation-related investment decisions.

4.8 Chair Education Field and R&D Intensity

The chair’s field of education plays a different role from that of the CEO. As the head of the board, the chair influences strategic oversight but does not engage in operational decision-making. For this reason, any association between education field and R&D

intensity is expected to be weaker. Nonetheless, it is important to examine whether systematic differences exist across groups.

Figure 8 displays the distribution of RD_Intensity_t by education field. The visual differences are modest: Chairs with Natural Science and Technology (NSTE) and multidisciplinary (Multi) backgrounds appear slightly higher, economics (Econ) occupies a middle position, and the “Other” and legal (Juridic) categories show very low levels with limited variation. Outliers appear primarily in the NSTE and Multi groups.

Figure 8. RD_Intensity_t by Chair_Edu_Field

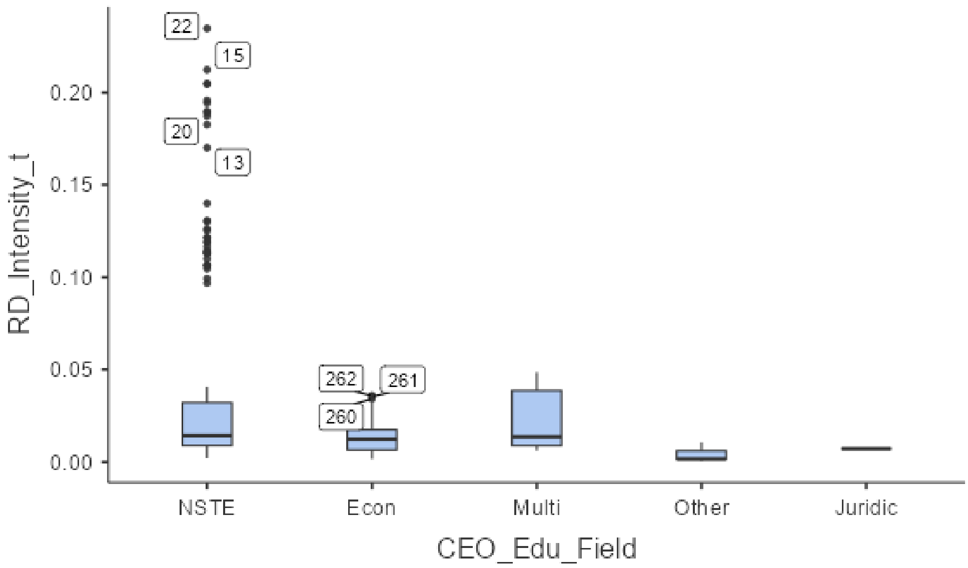


Table 24 shows that the Kruskal–Wallis test detects a statistically significant but weak overall difference ($\chi^2 = 9.93$, $p = 0.042$), with a small effect size ($\varepsilon^2 = 0.0336$). Education field explains only about 3.4% of the variation in R&D intensity—far less than in the CEO analysis.

Table 24. Kruskal–Wallis test for RD_Intensity_t by Chair_Edu_Field

	χ^2	df	p	ε^2
RD_Intensity_t	9.93	4	0.042	0.0336

Pairwise comparisons (Table 25) reveal that none of the group differences remain significant after adjustment. The closest cases—Econ vs Other (p = 0.095) and Other vs Juridic (p = 0.064)—still fall short of conventional thresholds.

Table 25. Pairwise comparisons (DSCF)

Group 1	Group 2	W	p
NSTE	Econ	0.287	1.000
NSTE	Other	3.359	0.122
NSTE	Juridic	-1.134	0.930
NSTE	Multi	-1.501	0.826
Econ	Other	3.508	0.095
Econ	Juridic	-1.811	0.703
Econ	Multi	-1.171	0.922
Other	Juridic	-3.726	0.064
Other	Multi	-2.574	0.362
Juridic	Multi	0.609	0.993

Overall, the results are economically and organisationally consistent. The chair's role is strategic and supervisory, and their educational background does not directly shape annual R&D spending. The weak and inconsistent differences across groups reinforce this interpretation.

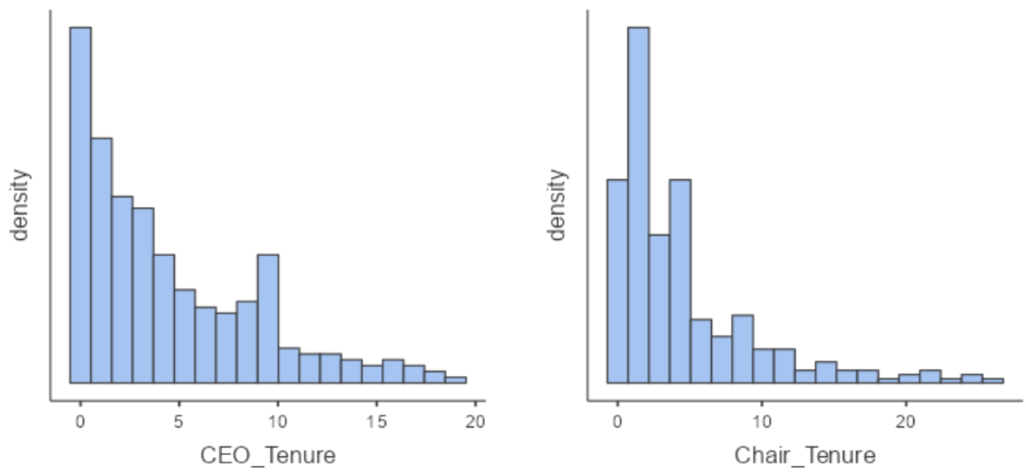
In summary, Chair_Edu_Field does not meaningfully explain variation in R&D intensity. The differences are small, statistically fragile, and far weaker than those observed for CEOs, indicating that the chair's educational background is not a strong indicator of a firm's innovation orientation.

4.9 CEO and Chair Tenure

The tenure of the CEO and the chair provides insight into leadership stability and turnover. Tenure is a continuous variable that reflects organisational dynamics and managerial career paths. Examining its distribution helps assess whether tenure functions as a natural control variable in later models.

Figure 9 presents the distribution of CEO tenure. The histogram is strongly right-skewed: most CEOs have served between 0 and 5 years, and long tenures are rare. The density declines steadily as tenure increases, a pattern typical in executive datasets where turnover is relatively frequent and only a few CEOs remain in office for more than a decade.

Figure 9. Histogram of CEO and chair tenure



The distribution of chair tenure, also shown in Figure 9, is nearly identical. Chair tenures are similarly right-skewed and concentrated at short durations. Very long tenures—particularly those exceeding 20 years—are uncommon and represent isolated cases. The similarity between the two distributions suggests that both leadership roles follow comparable turnover dynamics despite their different organisational functions.

Table 26 summarises the descriptive statistics. The mean CEO tenure is 4.40 years (median 3), while the corresponding values for chairs are 4.54 and 3 years. The standard deviations are comparable (4.50 vs 5.07), and both distributions include a minimum of 0 years, reflecting first-year appointments. Maximum values—19 years for CEOs and 26 years for chairs—are outliers rather than representative observations.

Table 26. Descriptive statistics for CEO_Tenure and Chair_Tenure

Statistic	CEO_Tenure	Chair_Tenure
N	297	297
Missing	0	0
Mean	4.40	4.54
Median	3	3
Standard deviation	4.50	5.07
Minimum	0	0
Maximum	19	26

Overall, the tenure distributions are economically and organisationally coherent. Executive tenures tend to be short, reflecting market pressures and boards' responsiveness to firm performance. Long tenures are exceptions and have limited influence on the overall distribution. The near-identical profiles of CEO and chair tenure indicate that both roles experience similar turnover patterns, supporting the use of tenure as a control variable in later regressions.

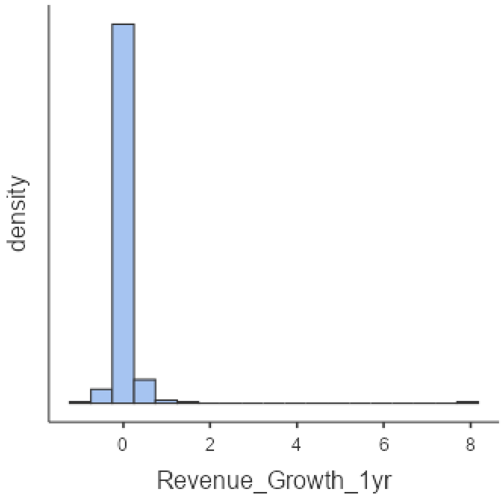
Methodologically, tenure is a continuous variable that does not require transformation or categorisation. Histograms and descriptive statistics are sufficient at the EDA stage, as tenure is not a primary variable of interest but a control intended to account for variation in managerial experience.

4.10 Distribution of Revenue_Growth_1yr

One-year revenue growth (Revenue_Growth_1yr) provides an initial view of how rapidly firms' top-line performance fluctuates over short horizons. Growth is inherently volatile and shaped by market demand, competitive dynamics, pricing power, cost structures, and discrete strategic decisions. For these reasons, the distribution is expected to be asymmetric and to include both negative outcomes and extreme positive spikes.

Figure 10 shows that the distribution is strongly right-skewed. Most observations cluster near zero, indicating that firms typically experience only modest annual revenue changes. The long right tail reflects a small number of firms undergoing exceptionally rapid expansion. Negative values, in turn, capture revenue contractions—an economically plausible outcome, especially in cyclical industries.

Figure 10. Histogram of Revenue_Growth_1yr



As shown in Table 27, one-year revenue growth exhibits substantial dispersion and strong right-skewness. The median (0.0240) is substantially lower than the mean (0.0619), confirming the skewness. The standard deviation (0.518) is large relative to the median, indicating considerable cross-firm variation. The minimum value (–0.922) corresponds to a near-halving of revenue, while the maximum (8.00) represents an extreme growth episode, typically associated with acquisitions, market entries, or major contracts.

Table 27. Descriptive statistics for Revenue_Growth_1yr

Statistic	Revenue_Growth_1yr
N	270
Missing	27
Mean	0.0619
Median	0.0240
Standard deviation	0.518
Minimum	–0.922
Maximum	8.00

Economically, the distribution is entirely plausible. Firm growth is known to be volatile and concentrated: most firms grow slowly, while a small subset experiences rapid expansion. This pattern aligns with the international literature, which characterises revenue growth as a “fat-tailed” variable.

Methodologically, the skewness implies that Revenue_Growth_1yr is not well suited for methods relying on normality without transformation. At the EDA stage, the histogram and descriptive statistics suffice, but later regressions require robust standard errors and non-parametric tests when assessing governance relationships.

In summary, Revenue_Growth_1yr is highly skewed and widely dispersed, reflecting the inherent volatility of firm growth. The distribution provides the foundation for examining governance–growth relationships in subsequent sections.

4.11 CEO Education Level and Revenue_Growth_1yr

The relationship between the CEO’s education level and one-year revenue growth offers insight into whether managerial human capital influences short-term financial performance. Education level is an ordinal variable capturing the depth of formal training and, potentially, the CEO’s ability to evaluate growth-related strategic decisions. It is therefore relevant to assess whether education level is associated with revenue growth before estimating the regression models.

Figure 11 plots CEO_Edu_Level against Revenue_Growth_1yr. The scatterplot shows no systematic trend: most observations cluster near zero growth, and the point cloud lacks upward or downward structure. The fitted line is nearly flat, and the few high-growth outliers appear randomly across categories rather than forming any pattern.

Figure 11. Scatter plot of CEO_Edu_Level and Revenue_Growth_1yr

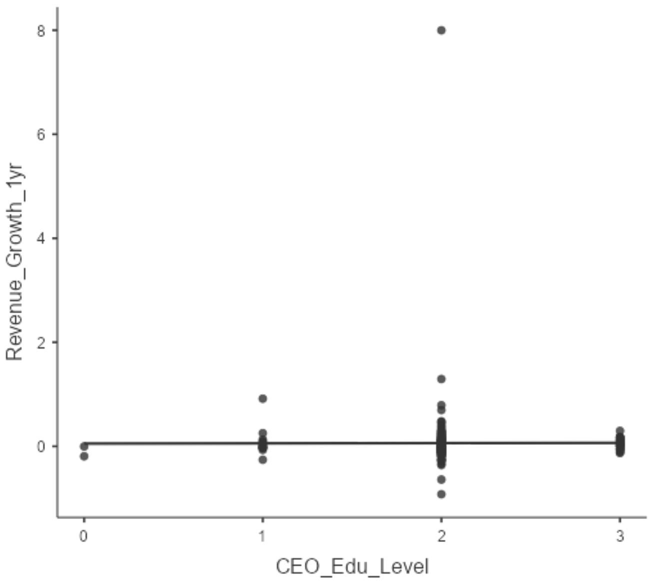


Table 28 confirms the absence of association. The Spearman correlation coefficient is $\rho = 0.089$ ($p = 0.143$, $N = 270$), indicating a weak and statistically insignificant relationship. The small positive value has no meaningful interpretative implications.

Table 28. Correlation matrix (Spearman): CEO_Edu_Level and Revenue_Growth_1yr

	Revenue_Growth_1yr	CEO_Edu_Level
Revenue_Growth_1yr	—	0.089
df	—	268
p-value	—	0.143
N	—	270
CEO_Edu_Level	0.089	—
df	268	—
p-value	0.143	—
N	270	—

Economically, the result is unsurprising. Short-term revenue growth is highly sensitive to market shocks, competitive shifts, and discrete strategic events. It is therefore expected that CEO education level does not meaningfully explain year-to-year variation in growth, unlike R&D intensity, which reflects long-term strategic orientation.

Methodologically, the finding indicates that CEO_Edu_Level does not add explanatory power to cross-firm variation in short-term growth. This contrasts with the R&D analysis, where education level exhibited a weak but systematic association.

In summary, CEO education level is not associated with Revenue_Growth_1yr. The relationship is statistically insignificant and economically negligible.

4.12 Chair Education Level and Revenue_Growth_1yr

The relationship between the chair's education level and one-year revenue growth provides a complementary governance perspective. The chair does not make operational decisions but influences strategic oversight. It is therefore reasonable to expect a weak or nonexistent relationship with short-term growth.

Figure 12 plots Chair_Edu_Level against Revenue_Growth_1yr. The scatterplot shows no discernible trend: observations form a diffuse cloud, the fitted line is flat, and high-growth outliers appear sporadically across categories.

Figure 12. Scatter plot of Chair_Edu_Level and Revenue_Growth_1yr

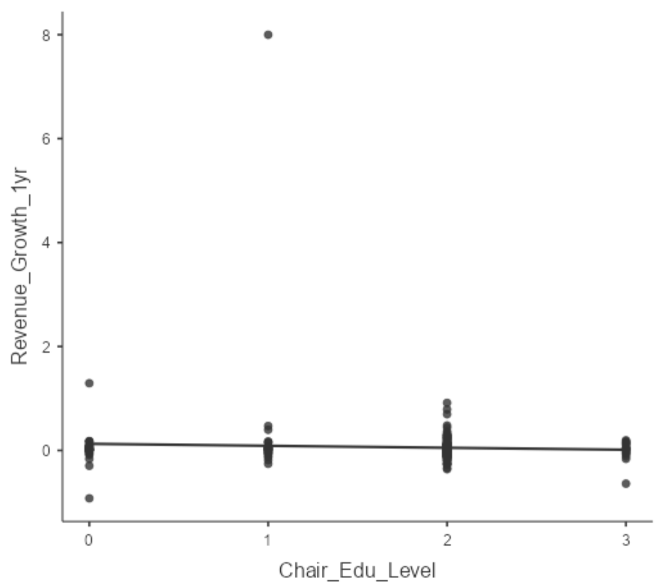


Table 29 confirms this impression. The Spearman correlation coefficient is ρ = –0.004 (p = 0.949, N = 270), effectively zero and far from statistical significance.

Table 29. Correlation matrix (Spearman): Chair_Edu_Level and Revenue_Growth_1yr

	Revenue_Growth_1yr	Chair_Edu_Level
Revenue_Growth_1yr	—	–0.004
df	—	268
p-value	—	0.949
N	—	270
Chair_Edu_Level	–0.004	—
df	268	—
p-value	0.949	—
N	270	—

Economically, the result is consistent with the chair’s role. Short-term revenue growth is driven by operational and market factors, not by board-level educational attributes. The contrast with R&D intensity—where the chair’s education level showed a weak but detectable pattern—highlights the difference between long-term innovation decisions and short-term financial outcomes.

Methodologically, Chair_Edu_Level does not contribute to explaining variation in Revenue_Growth_1yr and is not a central governance variable for growth models.

In summary, chair education level is unrelated to one-year revenue growth. The relationship is statistically insignificant and economically negligible.

4.13 CEO Education Field and Revenue_Growth_1yr

The CEO’s field of education offers a more detailed view of managerial expertise. Unlike education level, which captures depth, education field reflects the type of knowledge the CEO brings to strategic decision-making. It is therefore relevant to examine whether revenue growth differs across educational backgrounds.

Figure 13 presents Revenue_Growth_1yr by education field. The boxplots reveal no systematic differences: in all groups, most observations cluster near zero, and variation is limited. High-growth outliers appear sporadically and do not form group-specific patterns.

Figure 13. Revenue_Growth_1yr by CEO_Edu_Field

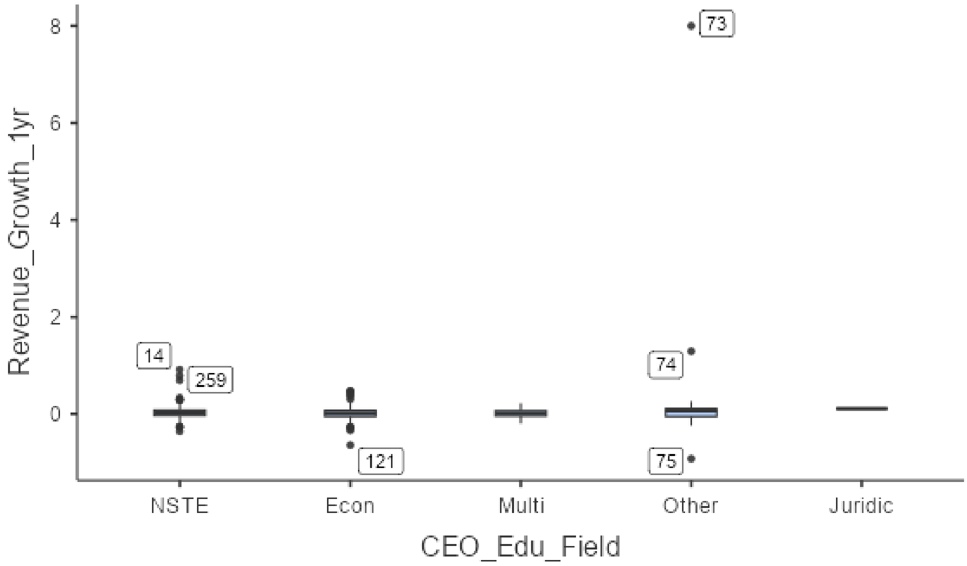


Table 30 confirms the absence of meaningful differences. The Kruskal–Wallis test yields $\chi^2 = 2.48$ (df = 4, p = 0.648), with a very small effect size ($\varepsilon^2 = 0.00922$). Education field explains less than 1% of the variation in revenue growth.

Table 30. Kruskal–Wallis test for Revenue_Growth_1yr by CEO_Edu_Field

	χ^2	df	p	ε^2
Revenue_Growth_1yr	2.48	4	0.648	0.00922

Pairwise comparisons (Table 31) reinforce this conclusion: none of the group differences are statistically significant, and p-values are uniformly high.

Table 31. Pairwise comparisons (DSCF)

Group 1	Group 2	W	p
NSTE	Econ	–1.129	0.931
NSTE	Multi	–0.760	0.984
NSTE	Other	0.987	0.957
NSTE	Juridic	1.466	0.839
Econ	Multi	–0.216	1.000
Econ	Other	1.274	0.897
Econ	Juridic	1.590	0.794
Multi	Other	0.977	0.959
Multi	Juridic	1.227	0.909
Other	Juridic	0.526	0.996

Economically, the result is expected. Short-term revenue growth is volatile and influenced by external shocks and competitive dynamics. It is therefore unlikely that the CEO's educational background—whether natural science and technology, economic, legal, or otherwise—systematically shapes one-year growth outcomes.

Methodologically, CEO_Edu_Field does not provide additional explanatory power for Revenue_Growth_1yr, in contrast to its substantial role in explaining R&D intensity.

In summary, CEO education field is not associated with one-year revenue growth. Differences across groups are statistically insignificant and economically weak.

4.14 Chair Education Field and Revenue_Growth_1yr

The relationship between the chair's field of education and one-year revenue growth offers insight into whether board-level expertise influences short-term financial performance. Given the chair's strategic and supervisory role—and the absence of operational decision-making authority—any association is expected to be weaker than for the CEO. Nevertheless, it is methodologically appropriate to examine whether growth differs systematically across educational backgrounds.

Figure 14 presents Revenue_Growth_1yr by education field. The boxplots reveal no clear or systematic differences: in all groups, most observations cluster near zero, and variation is limited. High-growth outliers appear sporadically across categories, without forming any discernible pattern.

Figure 14. Revenue_Growth_1yr by Chair_Edu_Field

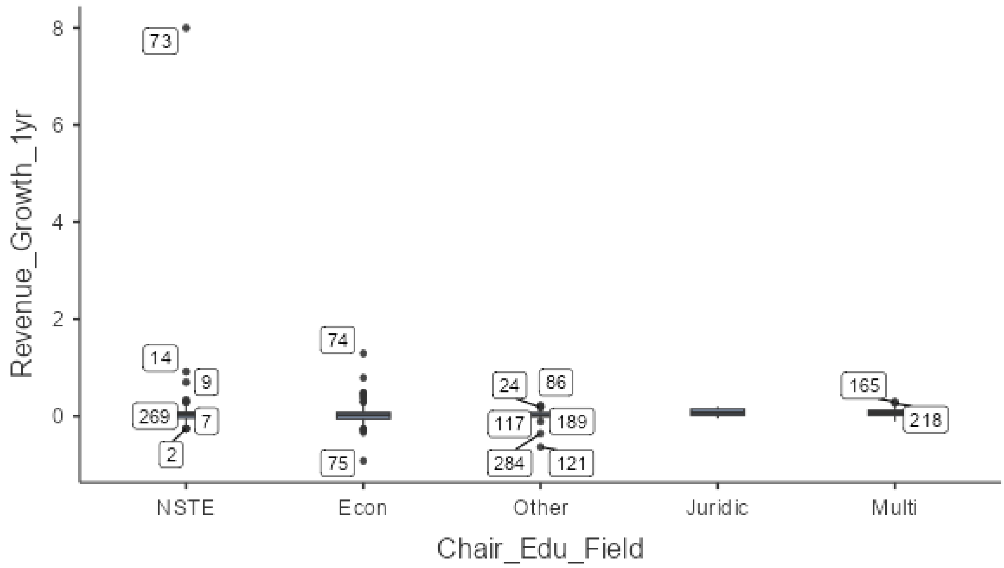


Table 32 confirms this impression. The Kruskal–Wallis test yields $\chi^2 = 5.97$ (df = 4, p = 0.201), with a small effect size ($\varepsilon^2 = 0.0222$). Education field explains only about 2.2% of the variation in revenue growth—an economically negligible share.

Table 32. Kruskal–Wallis test for Revenue_Growth_1yr by Chair_Edu_Field

	χ^2	df	p	ε^2
Revenue_Growth_1yr	5.97	4	0.201	0.0222

Pairwise comparisons (Table 33) reinforce this conclusion: none of the group differences are statistically significant, and p-values are uniformly high (0.193–1.000).

Table 33. Pairwise comparisons (DSCF)

Group 1	Group 2	W	p
NSTE	Econon	–0.8333	0.977
NSTE	Other	–0.0482	1.000
NSTE	Juridic	1.3262	0.882
NSTE	Multi	2.4002	0.436
Econ	Other	0.8599	0.974
Econ	Juridic	1.6686	0.763
Econ	Multi	3.0610	0.193
Other	Juridic	1.7194	0.743
Other	Multi	2.4331	0.421
Juridic	Multi	–0.3299	0.999

Economically, the result is intuitive. Short-term revenue growth is driven by market shocks, competitive dynamics, and operational decisions—factors outside the chair's direct influence. This contrasts with R&D intensity, where the chair's education field showed weak but observable patterns, reflecting the long-term nature of innovation decisions.

Methodologically, Chair_Edu_Field does not contribute meaningful explanatory power to variation in Revenue_Growth_1yr and is not a central governance variable for growth models.

In summary, the chair's field of education is not associated with one-year revenue growth. The differences across groups are statistically insignificant and economically weak.

4.15 CEO Tenure and Revenue_Growth_1yr

The relationship between CEO tenure and one-year revenue growth provides insight into whether managerial experience and organisational continuity influence short-term performance. Tenure is a continuous variable capturing institutional knowledge, strategic continuity, and internal stability. However, given the volatility of revenue growth, it is uncertain whether tenure can meaningfully explain its variation.

Figure 15 plots CEO_Tenure against Revenue_Growth_1yr. The scatterplot shows no systematic trend: observations form a diffuse cloud, the fitted line is nearly flat, and high-growth outliers appear randomly across the tenure range.

Figure 15. Scatter plot of CEO_Tenure and Revenue_Growth_1yr

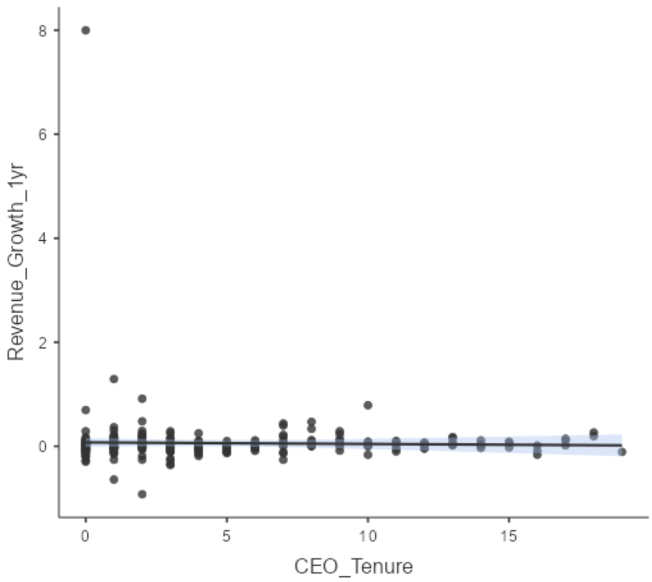


Table 34 reports a Spearman correlation of ρ = 0.130 (p = 0.032, N = 270). Although statistically significant at the 5% level, the magnitude is extremely small. The relationship is detectable but economically negligible, explaining only a trivial fraction of growth variation.

Table 34. Correlation matrix (Spearman): CEO_Tenure and Revenue_Growth_1yr

	CEO_Tenure	Revenue_Growth_1yr
CEO_Tenure	—	0.130
df	—	268
p-value	—	0.032
N	—	270
Revenue_Growth_1yr	0.130	—
df	268	—
p-value	0.032	—
N	270	—

Economically, the result is plausible. Short-term revenue growth is shaped by external shocks and competitive dynamics, whereas CEO tenure influences long-term strategic direction rather than year-to-year fluctuations. It is therefore expected that tenure does not meaningfully explain short-term growth.

Methodologically, the finding supports the use of tenure as a control variable but not as a substantive governance predictor in growth models.

In summary, CEO tenure is weakly but economically insignificantly associated with one-year revenue growth. The relationship exists statistically but lacks practical explanatory power.

4.16 Chair Tenure and Revenue_Growth_1yr

The relationship between chair tenure and one-year revenue growth provides a complementary governance perspective. The chair influences strategic direction and board oversight but does not engage in operational decision-making. It is therefore reasonable to expect little or no association with short-term revenue outcomes.

Figure 16 plots Chair_Tenure against Revenue_Growth_1yr. The scatterplot shows no trend: observations are widely dispersed, the fitted line is flat, and high-growth outliers appear randomly.

Figure 16. Scatter plot of Chair_Tenure and Revenue_Growth_1yr

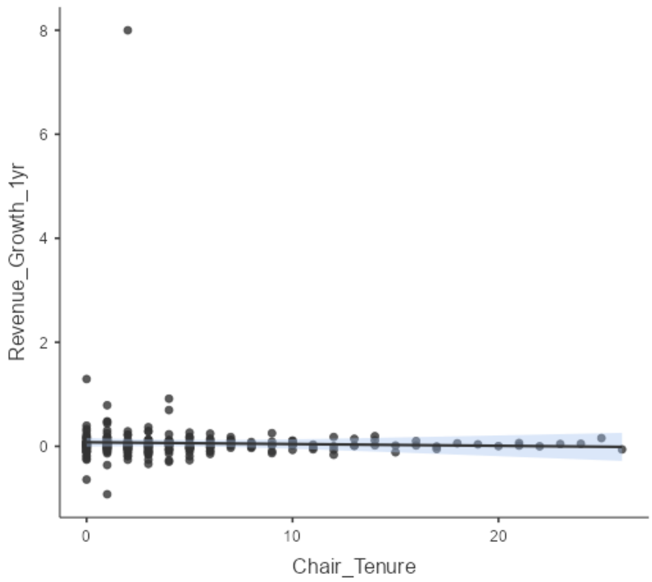


Table 35 confirms the absence of association. The Spearman correlation is ρ = 0.003 (p = 0.961, N = 270), effectively zero and far from statistical significance.

Table 35. Correlation matrix (Spearman): Chair_Tenure and Revenue_Growth_1yr

	Chair_Tenure	Revenue_Growth_1yr
Chair_Tenure	—	0.003
df	—	268
p-value	—	0.961
N	—	270
Revenue_Growth_1yr	0.003	—
df	268	—
p-value	0.961	—
N	270	—

Economically, the result is expected. Chair tenure affects board dynamics and long-term strategic continuity, not short-term revenue fluctuations. The absence of association is therefore consistent with the nature of the variable.

Methodologically, Chair_Tenure does not explain variation in Revenue_Growth_1yr and serves only as a control variable in later models.

In summary, chair tenure is unrelated to one-year revenue growth. The relationship is statistically insignificant and economically negligible.

4.17 Summary

The exploratory data analysis reveals that R&D intensity is the most persistent and structurally inert variable in the dataset. Its distribution is strongly right-skewed, and its autocorrelation is nearly perfect, explaining the near-unit coefficients observed in later regressions and the limited explanatory power of governance variables. ROI is more symmetric and less inert but still highly persistent, supporting the inclusion of ROI_t-1 as a control in the R&D → ROI models. The relationship between R&D intensity and ROI is weak but statistically significant, consistent with the multifaceted determinants of profitability.

Governance variables exhibit partially systematic relationships with R&D intensity. CEO education level shows a weak but consistent association, while education field explains a substantial share of variation: CEOs with technical or multidisciplinary backgrounds lead firms with higher R&D intensity. In contrast, the chair's education level and field have far weaker explanatory power, underscoring the CEO's operational role in innovation. Tenure variables are strongly right-skewed and serve as natural and informative controls.

Revenue_Growth_1yr is highly skewed and extremely dispersed, reflecting the inherent volatility of firm growth. Governance variables, however, show uniformly weak relationships with growth: neither education level, education field, nor tenure explains one-year revenue changes in a statistically or economically meaningful way. This contrasts sharply with R&D intensity, where CEO education field was a significant predictor. The randomness and market dependence of short-term growth manifest as minimal governance explanatory power.

Several governance variables are categorical. The ordinal CEO_Edu_Level is analysed using Spearman correlations, while the nominal CEO_Edu_Field and Chair_Edu_Field are examined using Kruskal–Wallis and DSCF tests. Binary variables such as Gender and Turnover do not produce informative visual relationships with continuous economic variables and are therefore omitted from EDA. In the regression models, all categorical variables—including Gender, Turnover, and education fields—are converted into dummy variables. Tenure variables are continuous and require no transformation.

The full correlation matrix, heatmap, and VIF diagnostics were reviewed as part of the internal assessment process and confirm the absence of multicollinearity and the independence of governance variables. Overall, the EDA provides a strong theoretical and methodological foundation for the subsequent regression analysis, allowing the persistence of R&D intensity, the stability of ROI, and the volatility of growth to be appropriately incorporated.

5 RESULTS

Throughout the results section, the statistical reliability of each coefficient is evaluated using the t-statistic, defined as the ratio between the estimated coefficient and its standard error ($t = \beta/SE$). As a general rule, absolute t-values below approximately 2 indicate that the effect cannot be considered statistically reliable, even if the coefficient itself is numerically large. Conversely, absolute t-values above this threshold suggest that the estimated effect is statistically meaningful. All interpretations in the following subsections follow this principle.

5.1 Governance and R&D intensity

This subsection examines whether governance variables explain firms' R&D intensity across different lag structures. The relationship was analysed in twelve pooled models, where R&D intensity entered with lags of 1, 3, and 5 years. The education level variable (Edu_Level) was treated as an ordinal variable (0–3), with the following categories: 0 = no higher education, 1 = Bachelor's degree, 2 = Master's degree, and 3 = doctoral degree. The Edu_Level coefficients therefore capture the association between a one-step increase in education level and R&D intensity.

Across all models, R&D intensity behaved as a highly persistent process. The coefficients on lagged R&D intensity ranged from $\beta = 0.98$ to $\beta = 1.01$ and were statistically significant in every specification, reflecting the dominant role of firms' own historical investment patterns. This dynamic structure explains the very high R^2 values (0.976–0.989) and also why governance variables do not exhibit systematic effects: most of the year-to-year variation in R&D intensity is explained by firms' past R&D behaviour rather than managerial characteristics.

Panel diagnostics indicated that fixed-effects estimation was unsuitable because the governance variables exhibited very limited within-firm variation and would have been eliminated by the FE transformation. Random-effects models were rejected by the Hausman test in all governance blocks, and the panel displayed heteroskedasticity, autocorrelation, and cross-sectional dependence. For these reasons, pooled OLS with Driscoll–Kraay standard errors was used as the primary estimator.

This pattern is also clearly visible in the model-specific estimates. As shown in Tables 36–39, the near-unit coefficients on lagged R&D intensity (β = 0.98–1.01 across all models; Tables 36–39) indicate that R&D intensity behaves as a highly persistent, firm-specific process. This persistence dominates the explanatory power of the models and helps explain why governance variables do not exhibit systematic effects: most of the year-to-year variation in R&D intensity is explained by firms' own historical investment patterns rather than managerial characteristics.

Firm size (ln_revenue) was included as a control variable in all models, but its effect was small and inconsistent. The coefficients ranged from β = –0.00004 to β = –0.00097 (Tables 36-39), and ln_revenue was not systematically significant in any of the governance blocks.

CEO education field (CEO_Edu_Field, reference: Econ)

Across the CEO-EduField models (M01–M03; Table 36), individual education fields did not produce consistent deviations from the Econ reference category. In the 1-year model M01, the coefficients for the education field categories were close to zero (e.g. Juridic β = 0.0009; Table 36), and none of the fields showed a meaningful association with R&D intensity. In the 3-year model M02, the coefficients remained small and statistically weak (e.g. Juridic β = –0.0012; Table 36), and the effects did not form a coherent pattern. In the 5-year model M03, the coefficient for a legal background became more negative (β = –0.0061; Table 36) and was statistically significant, but the magnitude was extremely small and the effect did not repeat across lag structures. Other fields (NSTE, Other, Multi) showed similarly small coefficients (all β between –0.0048 and +0.0020; Table 36) and no systematic pattern in direction or size.

Table 36. CEO governance variables and R&D intensity (Models M01–M03)

Variable	M01 β	M01 SE	M02 β	M02 SE	M03 β	M03 SE
RD_t-lag	1.0116***	—	0.9890***	0.0287	1.0107***	0.0359
ln(revenue)	–0.0001	—	–0.0005*	0.0004	–0.0007*	0.0005
Edu_Field: NSTE	0.0004	—	0.0006	0.0005	0.0001	0.0006
Edu_Field: Juridic	0.0009	—	–0.0012	0.0010	–0.0061***	0.0019
Edu_Field: Other	0.0001	—	–0.0011	0.0026	–0.0048*	0.0020
Edu_Field: Multi	0.0010	—	0.0020	0.0010	0.0018	0.0015
Tenure	–0.0000	—	0.0003**	0.0001	0.0003**	0.0001
Gender (F=1)	–0.0008	—	–0.0013	0.0011	–0.0006	0.0008
Turnover	–0.0001	—	0.0000	0.0009	0.0015	0.0016
N	270		216		162	
R^2	0.9875		0.9792		0.9765	
Adj. R^2	0.9868		0.9779		0.9750	

Note. Driscoll–Kraay standard errors in separate SE columns. *p < .10; **p < .05; ***p < .01. Reference category for EduField: Econ.

Chair education field (Chair_Edu_Field, reference: Econ)

The Chair_Edu_Field models (M07–M09; Table 37) produced a few statistically significant but inconsistent deviations from the Econ reference category. A legal background showed small negative coefficients across models (e.g. M07: β = –0.0026), while a Multi background showed small positive coefficients (e.g. M08: β = 0.0023). However, these effects were only a few tenths of a percentage point and did not remain stable across lag structures, indicating that they do not represent meaningful or systematic governance effects.

Table 37. Chair governance variables and R&D intensity (Models M07–M09)

Variable	M07 β	M07 SE	M08 β	M08 SE	M09 β	M09 SE
RD_t-lag	1.0024***	0.0208	0.9864***	0.0242	1.0110***	0.0273
ln(revenue)	–0.0001	0.0002	–0.0006	0.0004	–0.0009**	0.0004
Edu_Field: NSTE	–0.0011	0.0007	–0.0013	0.0012	–0.0001	0.0008
Edu_Field: Juridic	–0.0026***	0.0009	–0.0033	0.0021	–0.0014**	0.0006
Edu_Field: Other	0.0006	0.0004	0.0005	0.0009	0.0020*	0.0008
Edu_Field: Multi	0.0024**	0.0009	0.0023**	0.0011	0.0029***	0.0011
Tenure	0.0000	0.0001	0.0002***	0.0001	0.0003*	0.0002
Gender (F=1)	0.0047*	0.0025	0.0024	0.0061	0.0016	0.0080
Turnover	–0.0002	0.0006	0.0006	0.0011	0.0025	0.0021
N	270		216		162	
R^2	0.9885		0.9797		0.9770	
Adj. R^2	0.9878		0.9785		0.9756	

Note. Driscoll–Kraay standard errors in separate SE columns. *p < .10; **p < .05; ***p < .01. Reference category for EduField: Econ.

Education level (Edu_Level, ordinal 0–3)

Education level showed similarly weak and inconsistent results. In the CEO_Edu_Level models (M04–M06; Table 38), the coefficients ranged from β = 0.0005 to β = 0.0014, none of which were statistically meaningful. In the Chair_Edu_Level models (M10–M12; Table 39), the coefficients ranged from β = –0.0002 to β = 0.0008, with only a few weak signals (e.g. M12: β = 0.0008), but again the magnitudes were extremely small and did not form a coherent pattern across lag structures.

Table 38. CEO governance variables and R&D intensity (Models M04–M06)

Variable	M04 β	M04 SE	M05 β	M05 SE	M06 β	M06 SE
RD_t-lag	1.0112***	0.0223	0.9896***	0.0301	1.0098***	0.0384
ln(revenue)	–0.0000	0.0001	–0.0004	0.0003	–0.0006	0.0004
Edu_Level	0.0005	0.0010	0.0007	0.0014	0.0014	0.0015
Tenure	–0.0000	0.0001	0.0002**	0.0001	0.0002	0.0000
Gender (F=1)	–0.0007	0.0006	–0.0011	0.0008	–0.0006	0.0008
Turnover	–0.0000	0.0006	0.0001	0.0009	0.0013	0.0012
N	270		216		162	
R^2	0.9875		0.9790		0.9758	
Adj. R^2	0.9870		0.9782		0.9748	

Note. Driscoll–Kraay SE in separate columns. *p < .10; **p < .05; ***p < .01.

Table 39. Chair governance variables and R&D intensity (Models M10–M12)

Variable	M10 β	M10 SE	M11 β	M11 SE	M12 β	M12 SE
RD_t-lag	1.0010***	0.0208	0.9831***	0.0255	1.0067***	0.0272
ln(revenue)	–0.0002	0.0002	–0.0007	0.0004	–0.0010**	0.0004
Edu_Level	–0.0002	0.0002	0.0003	0.0002	0.0008***	0.0003
Tenure	0.0001	0.0001	0.0003***	0.0001	0.0004***	0.0001
Gender (F=1)	0.0051**	0.0026	0.0030	0.0062	0.0017	0.0077
Turnover	–0.0002	0.0005	0.0007	0.0015	0.0027	0.0017
N	270		216		162	
R^2	0.9881		0.9793		0.9767	
Adj. R^2	0.9876		0.9784		0.9758	

Note. Driscoll–Kraay SE in separate columns. *p < .10; **p < .05; ***p < .01.

Other governance variables

Other governance variables—tenure, gender, and management turnover—did not exhibit systematic effects. Although some coefficients were statistically significant in individual models (e.g. tenure in M03; Table 36), these effects did not repeat across lag structures and therefore cannot be interpreted as robust determinants of R&D intensity.

Summary: Governance → R&D

Governance variables do not explain R&D intensity relative to the Econ reference category. R&D intensity is primarily a firm-specific, highly persistent process in which past R&D investments are the strongest determinant of the current level. These results are consistent across all lag structures and robust to heteroskedasticity, autocorrelation, and cross-sectional dependence, as confirmed by the panel-data diagnostics.

5.2 R&D intensity and return on invested capital (ROI)

This subsection assesses how lagged R&D intensity is associated with return on invested capital. The relationship was analysed in three pooled models, where R&D intensity entered with lags of 1, 3, and 5 years. All three models produced highly consistent results: lagged R&D intensity had a strong, positive, and economically meaningful association with ROI when Driscoll–Kraay standard errors were applied.

The coefficients for R&D intensity ranged from β = 13.66 to β = 16.53 (Table 40), indicating that a one-unit increase in R&D intensity is associated with an increase of approximately 13–17 percentage points in ROI. This magnitude is substantial in a corporate finance context and represents the strongest and most robust effect observed in the entire empirical analysis. In the 1-year model M13, the coefficient was β = 16.53, suggesting a very large short-term profitability response to R&D investments. The 3-year model M14 produced a similarly strong coefficient (β = 14.50), and the 5-year model M15 showed a slightly smaller but still economically significant effect (β = 13.66). The stability of these coefficients across lag structures indicates that the positive impact of R&D intensity on ROI is not sensitive to the timing of the investment and persists over multiple years.

ROI itself also behaved as a highly persistent process. The coefficient on lagged ROI was approximately β = 0.82 in all three models (Table 40), demonstrating that firms' past profitability strongly predicts their current profitability. This persistence is consistent with the idea that ROI reflects long-term strategic positioning, competitive advantages, and accumulated intangible assets, all of which evolve slowly over time.

Firm size (ln_revenue) did not explain ROI in any of the models. The coefficients were small and negative (β between –0.054 and –0.060; Table 40) and did not reach statistical significance. This suggests that, within this sample, firm size does not systematically influence the return generated on invested capital once R&D intensity and past profitability are accounted for.

Table 40. R&D intensity and return on invested capital (Models M13–M15)

Variable	M13 (lag 1) β	M13 SE	M14 (lag 3) β	M14 SE	M15 (lag 5) β	M15 SE
Intercept	1.8367***	0.3596	1.8610***	0.4795	1.8729***	0.6990
RD_Intensity	16.5337***	5.5132	14.5031***	5.2649	13.6643***	5.2019
ROI_t_minus1	0.8169***	0.0279	0.8195***	0.0382	0.8213***	0.0578
ln(revenue)	–0.0541	0.2199	–0.0578	0.2671	–0.0598	0.3322
N	266		266		266	
R²	0.6605		0.6591		0.6583	
Adj. R²	0.6539		0.6525		0.6516	

Note. Driscoll–Kraay SE in separate columns. *p < .10; **p < .05; ***p < .01.

Interpretation of the R&D coefficient

Because R&D intensity is measured as a proportion of revenue (0–1 scale), the coefficient values (β = 13.66–16.53) represent the effect of a one-unit increase in R&D intensity, which would correspond to an unrealistically large change (e.g., from 0.00 to 1.00, meaning that 100% of revenue is allocated to R&D). In practice, firms' R&D intensity varies within a much narrower range, typically between 0.01 and 0.10. A more realistic interpretation is therefore that a 1 percentage-point increase in R&D intensity (e.g., from 0.03 to 0.04) is associated with an increase of approximately 0.13–0.17 percentage points in ROI. Similarly, a 5 percentage-point increase (e.g., from 0.03 to 0.08) corresponds to an increase of roughly 0.75–0.85 percentage points in ROI. This scaling does not change the substantive conclusion: the effect of R&D intensity on profitability remains economically meaningful, statistically robust, and consistent across all lag structures.

Although the unconditional association between lagged R&D intensity and ROI is weak ($r = 0.244$; $R^2 = 0.0595$; Table 18), the regression coefficient becomes large once past profitability is controlled for (β = 13.66–16.53 across Models M13–M15; Table 40). This pattern reflects the strong persistence of ROI itself, as documented in the exploratory analysis ($r = 0.845$ between ROI_t-1 and ROI_t; Table 17), which absorbs most of the unconditional variation in profitability. When ROI_t-1 is included in the model, the independent contribution of R&D intensity becomes visible: the explanatory power increases from 6% in the simple bivariate specification (Table 18) to approximately 66% in the full dynamic model ($R^2 = 0.6605$ in M13; Table 40), implying an improvement of roughly $\Delta R^2 \approx 0.60$. This constitutes a classic suppressed relationship, where the effect of R&D does not appear in simple correlations but emerges strongly once the dynamic structure of profitability is accounted for.

Summary: R&D → ROI

R&D intensity has a strong, positive, and economically significant association with return on invested capital at all examined lags. The effect is large in magnitude, stable across specifications, and represents the only governance-related or managerial variable in the broader analysis that consistently explains firm-level performance. These results highlight the central role of R&D investments in driving long-term profitability.

5.3 Governance and revenue growth

This subsection examines the relationship between governance variables and revenue growth over different time horizons. The relationship was analysed using twelve pooled models, where the dependent variable was revenue growth over 1-, 3-, and 5-year horizons. The education level variable (Edu_Level) was treated as an ordinal variable (0–3), with the following categories: 0 = no higher education, 1 = Bachelor's degree, 2 = Master's degree, and 3 = doctoral degree. The Edu_Level coefficients therefore capture the association between a one-step increase in education level and revenue growth. As expected, the explanatory power of the models was relatively low (R^2 0.05–0.29), reflecting the volatile and hard-to-predict nature of revenue growth.

Firm size (ln_revenue)

Firm size was the only variable that consistently showed a positive association with revenue growth across all models. The coefficients ranged as follows:

- 1-year growth: β = 0.08–0.09 (Tables 41 and 44)
- 3-year growth: β = 0.29–0.36 (Tables 42 and 45)
- 5-year growth: β = 0.42–0.52 (Tables 43 and 46)

Several of these coefficients were statistically significant according to the Driscoll–Kraay standard errors (e.g. models M20 and M23), although the magnitude of the effect remained small.

CEO governance variables and revenue growth

Across the CEO models, neither education field nor education level showed a systematic association with revenue growth. In the 1-year model M16 (Table 41), none of the education field categories deviated meaningfully from the Econ reference group. The same pattern appeared in the 3-year model M20 (Table 42) and the 5-year model M24 (Table 43). Although CEO_Edu_Field_Other produced a large coefficient in the 3-year model M20 (β = 3.3729; Table 42), the effect was not statistically robust once Driscoll–Kraay standard errors were applied.

Education level showed similarly weak and inconsistent effects. In the 1-year model M17 (Table 41), the coefficient was small (β = 0.0556). In the 3-year model M21 (Table 42), the coefficient increased (β = 0.2797), but the effect did not repeat across horizons. In the 5-year model M25 (Table 43), the coefficient remained positive (β = 0.4204), yet the overall pattern remained inconsistent. Taken together, the CEO-level governance variables did not form a coherent explanatory pattern for revenue growth.

Table 41. Governance and revenue growth (1-year): CEO models (M16–M17)

Variable	M16 β	M16 SE	M17 β	M17 SE
ln(revenue)	0.0769*	0.0394	0.0944**	0.0452
Edu_Field: NSTE	0.0498	0.0425	—	—
Edu_Field: Juridic	0.0262	0.1038	—	—
Edu_Field: Other	0.9499	0.7124	—	—
Edu_Field: Multi	–0.0767*	0.0458	—	—
Edu_Level	—	—	0.0556	0.0464
Tenure	–0.0091	0.0127	0.0023	0.0023
Gender (F=1)	–0.0451	0.0617	–0.0703	0.0638
Turnover	0.1935*	0.1038	0.2000	0.1230
N	270		270	
R^2	0.1552		0.0557	
Adj. R^2	0.1101		0.0249	

Note. Driscoll–Kraay standard errors in separate SE columns. *p < .10; **p < .05; ***p < .01. Reference category for EduField: Econ.

Table 42. Governance and revenue growth (3-year): CEO models (M20–M21)

Variable	M20 β	M20 SE	M21 β	M21 SE
ln(revenue)	0.2941**	0.1404	0.3582**	0.1702
Edu_Field: NSTE	0.1011	0.1199	—	—
Edu_Field: Juridic	0.2238	0.4445	—	—
Edu_Field: Other	3.3729	2.1877	—	—
Edu_Field: Multi	–0.2407*	0.1244	—	—
Edu_Level	—	—	0.2797*	0.1639
Tenure	–0.0720	0.0584	–0.0356	0.0228
Gender (F=1)	–0.3496	0.2213	–0.4792**	0.2360
Turnover	–0.0400	0.2782	–0.0120	0.2198
N	216		216	
R^2	0.2621		0.0930	
Adj. R^2	0.2227		0.0634	

Note. Driscoll–Kraay standard errors in separate SE columns. *p < .10; **p < .05; ***p < .01. Reference category for EduField: Econ.

Table 43. Governance and revenue growth (5-year): CEO models (M24–M25)

Variable	M24 β	M24 SE	M25 β	M25 SE
ln(revenue)	0.4211	NA	0.5208	0.3207
Edu_Field: NSTE	0.1858	NA	—	—
Edu_Field: Juridic	0.2172	NA	—	—
Edu_Field: Other	5.1900	NA	—	—
Edu_Field: Multi	–0.3393	NA	—	—
Edu_Level	—	—	0.4204*	0.2333
Tenure	–0.1077	NA	–0.0509	0.0377
Gender (F=1)	–0.4903	NA	–0.6763	0.4491
Turnover	–0.0843	NA	–0.0423	0.4063
N	162		162	
R^2	0.2876		0.0948	
Adj. R^2	0.2496		0.0652	

Note. Driscoll–Kraay standard errors in separate SE columns. *p < .10; **p < .05; ***p < .01. Reference category for EduField: Econ.

Chair governance variables and revenue growth

The Chair models produced a few statistically significant but inconsistent deviations from the Econ reference category. In the 1-year model M18 (Table 44), a Multi background showed a positive and statistically significant association with revenue growth (β = 0.0872). In the 3-year model M22 (Table 45), an Other background showed a marginally significant but economically weak negative association (β = –0.3299). In the 5-year model M26 (Table 46), none of the education field categories exhibited consistent effects across horizons.

Education level also produced weak and inconsistent signals. In the 1-year model M19 (Table 44), the coefficient was slightly negative (β = –0.0977). In the 3-year model M23 (Table 45), the effect was larger (β = –0.5439), but again did not repeat across horizons. In the 5-year model M27 (Table 46), the coefficient remained negative (β = –0.7828*), yet the pattern lacked consistency. Overall, the Chair-level governance variables did not provide systematic explanatory power for revenue growth.

Table 44. Governance and revenue growth (1-year): Chair models (M18–M19)

Variable	M18 β	M18 SE	M19 β	M19 SE
ln(revenue)	0.0934**	0.0433	0.1026**	0.0442
Edu_Field: NSTE	0.1666*	0.0856	—	—
Edu_Field: Juridic	0.0389	0.0432	—	—
Edu_Field: Other	–0.0398	0.0274	—	—
Edu_Field: Multi	0.0872***	0.0294	—	—
Edu_Level	—	—	–0.0977*	0.0514
Tenure	–0.0066	0.0054	–0.0141**	0.0066
Gender (F=1)	–0.1256**	0.0615	–0.1877**	0.0780
Turnover	–0.0213	0.0598	–0.0402	0.0562
N	270		270	
R^2	0.0609		0.0615	
Adj. R^2	0.0108		0.0308	

Note. Driscoll–Kraay standard errors in separate SE columns. *p < .10; **p < .05; ***p < .01. Reference category for EduField: Econ.

Table 45. Governance and revenue growth (3-year): Chair models (M22–M23)

Variable	M22 β	M22 SE	M23 β	M23 SE
ln(revenue)	0.3857**	0.1931	0.4084**	0.2020
Edu_Field: NSTE	–0.1638	0.2563	—	—
Edu_Field: Juridic	–0.5778	0.5458	—	—
Edu_Field: Other	–0.3299*	0.1785	—	—
Edu_Field: Multi	–0.1261	0.2313	—	—
Edu_Level	—	—	–0.5439*	0.2784
Tenure	–0.0266**	0.0133	–0.0484**	0.0207
Gender (F=1)	–0.7377*	0.4449	–0.6239*	0.3495
Turnover	0.6274	0.5235	0.5527	0.4722
N	216		216	
R^2	0.1199		0.1718	
Adj. R^2	0.0729		0.1448	

Note. Driscoll–Kraay standard errors in separate SE columns. *p < .10; **p < .05; ***p < .01. Reference category for EduField: Econ.

Table 46. Governance and revenue growth (5-year): Chair models (M26–M27)

Variable	M26 β	M26 SE	M27 β	M27 SE
ln(revenue)	0.5628	0.3744	0.5924	0.3819
Edu_Field: NSTE	–0.3541	0.4526	—	—
Edu_Field: Juridic	–0.8988	1.3175	—	—
Edu_Field: Other	–0.5148	0.3173	—	—
Edu_Field: Multi	–0.1695	0.4434	—	—
Edu_Level	—	—	–0.7828*	0.4362
Tenure	–0.0381	0.0327	–0.0688*	0.0410
Gender (F=1)	–1.0793	0.9566	–0.8688	0.7493
Turnover	0.9585	0.8553	0.8527	0.7888
N	162		162	
R^2	0.1257		0.1761	
Adj. R^2	0.0790		0.1491	

Note. Driscoll–Kraay standard errors in separate SE columns. *p < .10; **p < .05; ***p < .01. Reference category for EduField: Econ.

Other governance variables

Tenure, gender, and management turnover did not exhibit systematic effects. Although some coefficients reached statistical significance in individual models (e.g. tenure in M23; Table 45), these effects did not repeat across horizons and therefore cannot be interpreted as robust determinants of revenue growth.

Summary: Governance → Growth

Governance variables do not systematically explain revenue growth. The CEO's and Chair's education field and level produce small and inconsistent effects relative to the Econ reference. Firm size is the only consistently positive explanatory variable, but its effect is small.

5.4 Overall summary of results

The results from the three model families form a coherent picture in which the direct effects of governance variables remain weak, while the role of R&D intensity in financial performance is pronounced.

- Governance → R&D: Governance variables do not explain R&D intensity; R&D is a highly persistent, firm-specific process.
- R&D → ROI: R&D intensity has a strong, positive, and economically significant effect on ROI at all lags.
- Governance → Growth: Governance variables do not explain revenue growth; the observed effects are small and inconsistent.
- Edu_Level: Edu_Level is an ordinal variable (0–3), and its effects are small throughout and do not form a systematic explanatory pattern.

5.5 Robustness and diagnostic checks

All results were subjected to an extensive robustness and diagnostic audit. The full set of panel-data diagnostics (including tests for heteroskedasticity, autocorrelation, and cross-sectional dependence), multicollinearity checks, cluster-robust and Driscoll–Kraay standard errors, and model-agnostic residual analyses was reviewed as part of the internal assessment process but is not included in the public version of this thesis. These diagnostics confirm that the main findings are not driven by model misspecification, dependence structures, or outlier behaviour.

Fixed-effects models were not appropriate because governance variables exhibit minimal within-firm variation and would be eliminated by the FE transformation. Random-effects models were rejected by the Hausman test across all governance blocks, indicating that the RE assumptions do not hold. Therefore, pooled OLS with Driscoll–Kraay standard errors was selected as the most suitable estimator.

6 DISCUSSION

6.1 Key Findings

The results of this study form three coherent themes that align naturally with both the literature review and the methodological choices. First, executives' background characteristics—field of education, level of education, gender, tenure, and turnover—do not explain firms' R&D intensity or revenue growth. This is consistent with prior research showing that the effects of CEO and chair education on firm performance are generally weak and highly context-dependent (Gottesman & Morey, 2006; Jalbert, Rao, et al., 2011; Phan, 2016). Second, R&D intensity exhibits a strong and economically meaningful positive association with return on invested capital (ROI), underscoring the central role of R&D investments in strengthening firm-level productivity and profitability. Third, both R&D intensity and ROI are highly persistent processes, which is expected in dynamic investment environments and reinforces the economic credibility of the findings.

Methodologically, these results are coherent: the limited variation and near time-invariance of governance variables, combined with the structural constraints of the pooled OLS model, explain why their effects are not detected. At the same time, the use of Driscoll–Kraay robust standard errors and a comprehensive audit process confirm that the results are not statistical artefacts. Together, these findings suggest that firm-level performance dynamics in Finland are driven more by structural and strategic factors than by executive demographics.

6.2 Executive Backgrounds and R&D Intensity

The literature on the impact of executives' educational and demographic characteristics on strategic choices has produced mixed and context-specific findings. Several studies show that education does not systematically explain firm performance (Gottesman & Morey, 2006; Jalbert, Rao, et al., 2011; Morresi, 2017), and this study confirms the same phenomenon in the Finnish context: executive background variables do not explain R&D intensity.

The methodological explanation is straightforward. Governance variables are nearly time-invariant, and their variation among Finnish listed firms is limited: 81% of CEOs and

78% of board chairs hold a master's degree, and only a small minority hold doctorates. Such homogeneity restricts both statistical identification and substantive explanatory power. Moreover, pooled OLS is the only model capable of identifying the effects of governance variables, as fixed-effects models would eliminate them entirely and random-effects models are misspecified. This methodological constraint is an essential part of interpreting the results: the absence of governance effects is unsurprising when the underlying variation is structurally limited.

The findings also align with literature suggesting that education explains compensation better than performance (Atkinson & Blundell-Wignall, 2021), and that executive effectiveness is driven more by personality, cognitive capacity, and learning agility than by degree level (De Meuse, 2019; Martínez et al., 2025). This helps explain why the educational backgrounds of executives in Finnish listed firms do not form a systematic explanatory model for R&D strategies.

6.3 R&D Intensity and ROI: A Strong and Consistent Relationship

The clearest and economically most significant finding of the study is the strong positive relationship between R&D intensity and ROI. This complements the literature review, where executive background variables showed weak effects: while governance variables do not explain profitability, R&D investments do.

Methodologically, the result is credible for two reasons:

1. ROI is a dynamic process, and its lag (~0.82) indicates strong persistence, which is typical in profitability models.
2. Driscoll–Kraay robust standard errors ensure that the result is not driven by heteroskedasticity, autocorrelation, or cross-sectional dependence.

In Finnish listed firms, R&D investments are focused and productivity-oriented, which explains why they affect ROI but not revenue growth. This mechanism aligns with literature showing that development-oriented R&D improves efficiency and capital productivity but does not necessarily expand markets, generate new demand, or increase turnover. The results also indicate that the effect of R&D intensity becomes visible only once the dynamic structure of profitability is taken into account. In simple correlations the relationship appears weak, but when past profitability is controlled for, the independent contribution of R&D emerges clearly. This pattern reflects a suppressed relationship in which the strong persistence of ROI masks the unconditional association between R&D and profitability.

Although the relationship between R&D intensity and ROI is statistically strong and economically meaningful, the magnitude of the effect is modest relative to the size of typical R&D investments. Because R&D intensity is measured as a proportion of revenue, even a 1–5 percentage-point increase in R&D intensity represents a substantial financial commitment for a listed firm. The corresponding increase in ROI—approximately 0.13–0.85 percentage points depending on the scale of the investment—is positive but not large enough to offset the short-term cost of additional R&D expenditure. This implies that, within the time horizons examined in this study, R&D investments are *strategically valuable but not immediately profitable*. The results therefore support the view that R&D should be understood as a long-term capability-building investment rather than a short-term ROI-maximising decision.

6.4 Finnish R&D Is More Development (D) Than Research (R)

The results indicate that Finnish R&D activity is predominantly development-oriented rather than research-oriented. This pattern helps explain why R&D intensity is strongly associated with profitability but not with revenue growth. Development-focused R&D enhances efficiency and capital productivity, yet it does not create new markets or shield firms from intensifying competition (OECD, 2020, 2022).

The development-oriented nature of Finnish R&D can be understood in light of several structural characteristics of the Finnish business environment. These include the relatively conservative risk preferences of domestic ownership, the small average size of Finnish firms, the industry composition of the economy—where many sectors are traditionally low in research intensity—and the accounting treatment of R&D under IFRS, which incentivizes development expenditures over research. Collectively, these factors create an environment in which firms prioritize incremental improvements and operational efficiency rather than long-horizon research aimed at generating new knowledge or markets.

From the perspective of the literature review, this contrast is noteworthy: although executive background variables do not explain R&D intensity, R&D intensity itself explains profitability. This highlights that strategic investment decisions are shaped more by firm-level structures, capabilities, and incentives than by the demographic characteristics of individual executives.

It is important to emphasise that these findings apply specifically to large and mid-sized Finnish listed firms reporting under IFRS. The sample does not include small or non-listed firms, many of which operate in technology-intensive niches and exhibit substantially higher R&D intensity. IFRS accounting rules also structurally lower reported R&D intensity by favouring development expenditure over research. Therefore, the results should not be generalised to the broader Finnish business sector, where R&D profiles may differ significantly.

6.5 Executive Backgrounds and Revenue Growth

The effects of executive background variables on revenue growth proved weak and inconsistent. This aligns with the literature review, where growth was shown to be particularly sensitive to external factors such as market demand, competition, and industry dynamics. Growth is also a far more volatile variable than ROI, making it statistically more difficult to explain.

Studies on tenure and turnover indicate that leadership changes and tenure effects are often context-dependent and nonlinear. The results of this study—where no effects were detected—are consistent with the view that demographic backgrounds do not form a systematic explanatory model for growth. This reinforces the conclusion that revenue growth is shaped primarily by external market conditions and strategic choices rather than by executive characteristics.

6.6 Methodological Considerations and Reliability of Results

Several methodological factors strengthen the reliability of the findings. The limited variation and near time-invariance of governance variables restrict their explanatory power but do not undermine the results. Pooled OLS was the only method capable of identifying governance effects, as fixed-effects models would eliminate them and random-effects models were misspecified.

Driscoll–Kraay robust standard errors correct for heteroskedasticity, autocorrelation, and cross-sectional dependence—common issues in panel data. In addition, the extensive audit process (data audit, model audit, and results audit) ensures that the findings are not artefacts of data quality, model specification, or reporting errors.

6.7 Limitations

The study has several limitations that should be considered when interpreting the results:

- the sample consists of 27 Finnish listed firms
- variation in executive background variables is limited
- IFRS-based measurement of R&D intensity involves known challenges
- endogeneity cannot be fully ruled out

These limitations do not, however, weaken the central finding of a strong relationship between R&D intensity and ROI.

6.8 Macroeconomic Perspectives

The results suggest that the Finnish economy could benefit from increased R&D investment. A recent report by Sitra (Pohjola, 2025) shows that Finland’s stagnating economic growth is driven by weak productivity in the market sector and, in particular, by the low contribution of intangible capital compared to peer countries (OECD, 2016, 2020, 2022). According to the report, R&D investments are a key mechanism for restoring productivity growth in the market sector.

This macro-level observation is consistent with the findings of this study: R&D intensity is strongly associated with firm-level profitability (ROI), supporting the theory of productivity-driven economic growth (OECD, 2020, 2022). At the same time, the results show that R&D intensity does not explain revenue growth, which aligns with Sitra’s conclusion that Finnish R&D improves efficiency but does not yet scale into new markets and create growth.

In the long run, the greatest risk arises when research-oriented R&D is not conducted. According to Sitra, Finland’s future growth depends on high-productivity services and the adoption of new innovations (Pohjola, 2025). Without the creation of new knowledge and new markets, firms' strategic room for manoeuvre narrows and economic dynamism weakens (OECD, 2025). In this sense, increasing research-oriented R&D is not risk-taking but risk management. The firm-level findings therefore mirror the macroeconomic challenge: efficiency-enhancing R&D is abundant, but research-driven innovation remains insufficient to generate new growth trajectories.

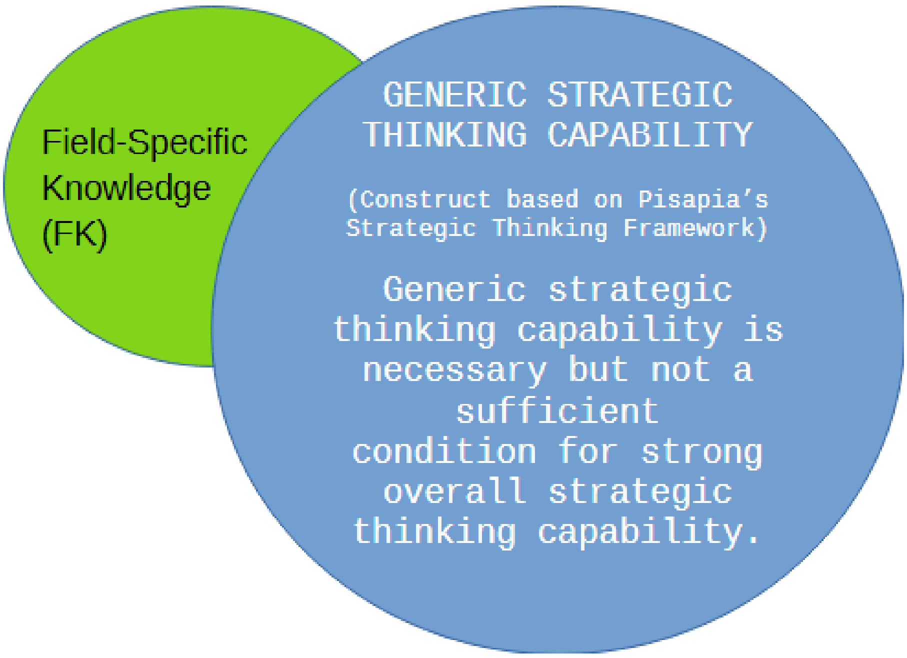
6.9 The Strategic Thinking Perspective

Some researchers suggest that firms' ability to benefit from R&D investments depends not only on resources but also on the quality of leadership and strategic thinking. The strategic thinking literature highlights capabilities such as long-term vision, uncertainty management, systems thinking, temporal integration, and the effective use of intangible assets (Liedtka, 1998; Mintzberg, 1991; Pisapia, 2009). These perspectives emphasise that strategic thinking is a cognitive and organisational capability rather than a demographic attribute, which helps explain why executive background variables do not systematically predict R&D intensity or revenue growth in this study.

A recurring theme in this literature is that strategic thinking integrates analytical reasoning, temporal awareness, and the ability to reframe problems under uncertainty. These capabilities influence how firms interpret technological opportunities, allocate attention, and convert R&D investments into economic outcomes. From this viewpoint, the absence of governance effects in the empirical results is unsurprising: demographic indicators such as degree level or tenure do not capture the cognitive processes through which strategic decisions are formed.

A further dimension highlighted in practice-oriented research is the role of contextual knowledge. Strategic thinking is exercised within specific industries, each with its own technological base, competitive logic, and knowledge structures. Effective strategic judgement therefore depends on understanding this context and recognising the knowledge base of one's own and related fields (Figure 17) (Varis, 2023; Varis, 2025). This helps explain why demographic variables do not predict R&D intensity: such background indicators are too coarse to capture the field-specific expertise required to evaluate technological trajectories or development opportunities. In this study, even the executives' field of education showed no association with R&D intensity, suggesting that educational background alone does not adequately reflect the contextual understanding relevant for strategic R&D decisions.

Figure 17. Relationship between FK and strategic thinking capability.



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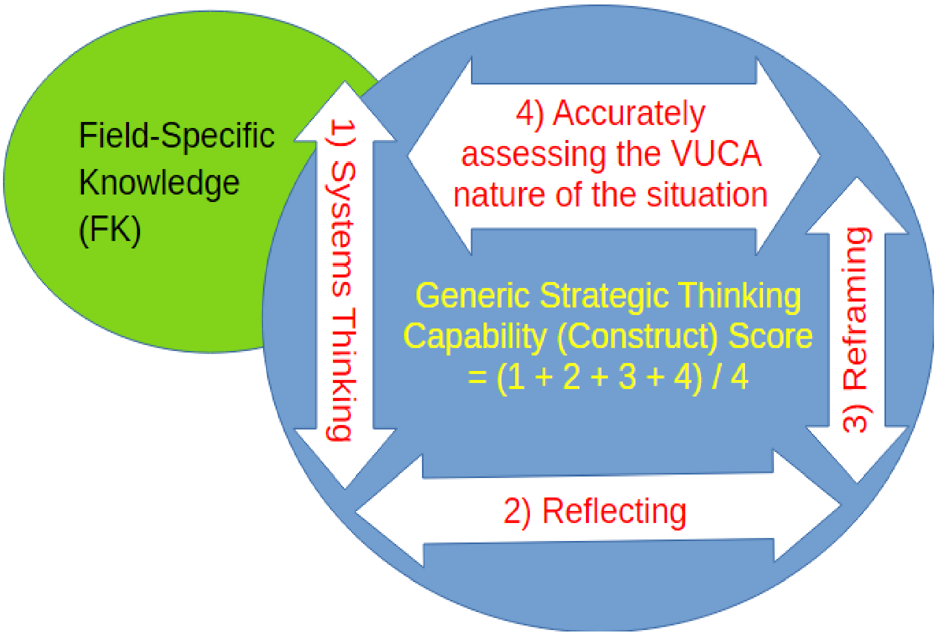
Strategic thinking research also emphasises the importance of interpreting environmental uncertainty. Development-oriented R&D improves efficiency and capital productivity in relatively stable environments, whereas research-oriented R&D requires the ability to interpret high-VUCA conditions and envision new markets (Figure 18) (Varis, 2023; Varis, 2025). This distinction aligns with the empirical results of this study, where R&D intensity predicts ROI but not revenue growth.

Figure 18. Components of generic strategic thinking capability.



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This interpretation is consistent with broader macroeconomic analyses. Sitra's report (Pohjola, 2025) attributes Finland's growth challenges to weak productivity and slow structural transformation. Without sufficient strategic capability, R&D investments tend to concentrate on development and efficiency improvements rather than on creating new knowledge, markets, or business models. This provides a plausible explanation for why executive background variables do not explain R&D intensity, while R&D intensity does explain profitability (OECD, 2020, 2022).

Contemporary strategy research further highlights that strategic thinking is not only an individual cognitive capability but also a collective process shaped by team dynamics, divergent interpretations, and shared sensemaking. Studies show that managerial attention is shaped less by demographic traits and more by emotional and structural mechanisms that determine which issues become strategically salient (Vuori, 2024). Research on cognitive diversity indicates that performance effects are non-linear, meaning that individual background variables cannot capture the emergent cognitive properties of top management teams (Kumbure et al., 2020). Other work demonstrates that strategic cognition affects firm outcomes only when paired with complementary capabilities such as innovativeness, risk-taking, and relevant experience — dimensions that demographic indicators do not reflect (Attah-Boakye et al., 2023). Additional evidence shows that strategic cognition functions as the mechanism through which firms translate external and internal opportunities into concrete strategic action (Zang et al., 2025), and that performance depends not on the level of strategic cognition alone but on the alignment between strategic thinking and strategic action (Lei et al., 2025).

Strategic cognition also extends beyond internal managerial processes. It includes the ability to interpret broader societal, environmental, and ethical developments that increasingly shape firms' operating conditions. As expectations related to sustainability, responsibility, and long-term value creation intensify, organisations must be able to integrate these external signals into their strategic thinking. This broader cognitive capacity influences how firms balance research-oriented and development-oriented R&D and determines whether R&D investments are used merely to enhance efficiency or to build new capabilities for future competitiveness.

Taken together, these perspectives converge on a single conclusion: the effectiveness of R&D investments is determined by an organisation's strategic cognition — its collective ability to interpret opportunities, allocate attention, and translate strategic thinking into coherent action — rather than by the demographic characteristics of individual executives. This underscores the need for future research to focus on cognitive and organisational mechanisms instead of demographic proxies when explaining how firms transform R&D investments into economic performance.

7 CONCLUSIONS

This study examined how executives' background characteristics, R&D intensity and firm performance are related in Finnish listed companies. Drawing on an 11-year panel of 27 firms, the analysis provides a rare long-horizon view of how leadership demographics, strategic investment behaviour and financial outcomes evolve over time. The research addressed three core questions: whether executives' background variables explain firms' R&D intensity, whether they explain revenue growth, and how R&D intensity relates to profitability and growth.

The findings are clear and consistent. Neither the level nor the field of executives' education—nor gender, tenure or turnover—explains firms' R&D intensity or revenue growth. This result aligns with the broader governance literature, which shows that executive demographics are weak and context-dependent predictors of firm performance. In contrast, R&D intensity exhibits a strong and economically meaningful positive association with ROI, underscoring the central role of R&D investments in strengthening firm-level productivity and profitability. At the same time, R&D intensity does not explain revenue growth, indicating that Finnish R&D activity enhances efficiency rather than expanding markets. Both R&D intensity and ROI are highly persistent processes, reinforcing the economic credibility of the results.

The study makes several theoretical contributions. First, it strengthens the view that executive demographics are poor predictors of strategic thinking and investment behaviour, particularly in institutional contexts where leadership profiles are highly homogeneous. Second, it contributes to the R&D literature by showing that R&D intensity is a key mechanism behind profitability but not growth, highlighting the distinction between development-oriented and research-oriented R&D. Third, it provides a structural explanation for the Finnish R&D profile: conservative ownership preferences, small firm size, industry composition and IFRS accounting practices collectively favour development-focused R&D over long-horizon research.

The findings also carry practical implications. For firms, the results suggest that strategic capability — particularly strategic thinking — determines the effectiveness of R&D investments. Although R&D intensity is strongly associated with higher ROI, the economic magnitude of the effect is modest relative to the size of typical R&D investments. Because R&D intensity is measured as a proportion of revenue, even a small increase represents a substantial financial commitment for a listed firm, while the corresponding short-term improvement in ROI remains limited. This implies that R&D investments are strategically valuable but not immediately profitable: they strengthen long-term capabilities and productivity rather than generating rapid financial returns. Firms therefore benefit from evaluating R&D decisions through long-horizon strategic lenses rather than short-term ROI maximisation.

Boards and owners may benefit from reassessing their risk preferences and investment horizons, particularly if R&D portfolios are heavily weighted toward incremental development. For policymakers, the results support national efforts to strengthen research-oriented R&D, given its importance for long-term productivity and growth. The firm-level evidence mirrors the macroeconomic challenge identified in recent analyses: efficiency-enhancing R&D is abundant in Finland, but research-driven innovation remains insufficient to generate new growth trajectories.

The study has limitations. The sample consists of 27 Finnish listed firms, and although the 11-year panel mitigates the small cross-section, broader datasets would strengthen generalizability. Executive background variables exhibit limited variation, which constrains statistical identification. IFRS-based measurement of R&D intensity involves known challenges, and endogeneity cannot be fully ruled out. These limitations do not, however, weaken the central finding of a strong relationship between R&D intensity and profitability.

Future research could examine how strategic thinking, organizational cognition and leadership practices shape R&D strategies and their economic outcomes. Further work could also distinguish more precisely between research- and development-oriented R&D, explore the role of ownership structure and risk preferences, and extend the analysis to other Nordic or European contexts. Understanding how firms convert R&D investments into long-term growth remains a critical question for both corporate strategy and national innovation policy.

In summary, this study shows that executive background characteristics do not explain firms’ R&D intensity or growth, whereas R&D intensity strongly predicts profitability. Finnish R&D is predominantly development-oriented, reflecting structural features of the business environment. The effectiveness of R&D investments depends less on who leaders are and more on the strategic capabilities of the organizations they lead.

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