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How R&D Intensity affect Operational Efficiency and Strategic Alliances in Medium-Sized Companies?

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A B S T R A C T

This study aims to investigate the impact of R&D intensity on operational efficiency and strategic alliances in medium-sized companies. Specifically, it seeks to understand how these variables interact to influence a firm's commitment to research and development activities, ultimately affecting their innovation and market performance. A cross-sectional design was employed, with a sample of 230 participants drawn from medium-sized companies. The sample size was determined using the Morgan and Krejcie table. Data were collected through structured questionnaires assessing R&D intensity, operational efficiency, and strategic alliances. Pearson correlation analysis was conducted to examine the relationships between the dependent variable (R&D intensity) and each independent variable (operational efficiency and strategic alliances). Linear regression analysis was performed to explore the combined effect of the independent variables on R&D intensity. All analyses were conducted using SPSS version 27. Pearson correlation coefficients indicated significant positive relationships between R&D intensity and operational efficiency ($r = 0.53$, $p = 0.001$), and between R&D intensity and strategic alliances ($r = 0.47$, $p = 0.002$). The regression analysis showed that operational efficiency and strategic alliances together explain 40% of the variance in R&D intensity ($R^2 = 0.40$, $F(2, 227) = 19.25$, $p = 0.000$). Multivariate regression results confirmed that both operational efficiency ($B = 0.07$, $\beta = 0.42$, $p =$

0.001) and strategic alliances (B = 1.10, β = 0.35, p = 0.000) are significant predictors of R&D intensity. The study concludes that operational efficiency and strategic alliances significantly enhance R&D intensity in medium-sized companies. These findings suggest that improving operational processes and fostering strategic partnerships are critical for increasing a firm's investment in research and development. The results are consistent with previous research and provide valuable insights for both academia and industry practitioners. Future research should consider longitudinal designs and explore additional variables to further understand these relationships.

Keywords: *R&D Intensity, Operational Efficiency, Strategic Alliances, Medium-Sized Companies, Innovation, Research and Development, Cross-Sectional Study.*

Introduction

Research and Development (R&D) intensity, defined as the ratio of a company's R&D expenditure to its total sales, is a key indicator of its commitment to innovation (Janjić et al., 2021). High R&D intensity reflects a strategic focus on developing new products, processes, and technologies that can enhance competitiveness and market share. Kraiczy, Hack, and Kellermanns (2014) highlight the role of CEO innovation orientation in driving R&D intensity in small and medium-sized firms, emphasizing the importance of leadership in fostering an innovative culture (Kraiczy et al., 2014).

R&D intensity is not only about financial commitment but also involves strategic decision-making regarding the allocation of resources towards innovative activities (Jin & Lee, 2020). The effectiveness of these investments can be seen in the enhanced innovation capabilities and business performance of companies, particularly in technology-driven sectors (Jin & Choi, 2019).

Operational efficiency, the ability to deliver products or services in the most cost-effective manner without compromising quality, is a critical outcome of effective R&D activities. Improved operational efficiency can result from the implementation of innovative processes and technologies developed through R&D (Walter et al., 2014). Companies that invest heavily in R&D tend to streamline their operations, reduce waste, and enhance productivity, which collectively contribute to better financial performance.

Xu and Jaewoo (2018) examine corporate R&D investment in emerging markets, revealing that efficient R&D processes lead to significant improvements in operational performance (Xu & Jaewoo, 2018). Similarly, Shin et al. (2019) demonstrate that government R&D subsidies can enhance the operational efficiency of biotechnology firms, highlighting the role of public policy in supporting R&D activities (Shin et al., 2019).

Strategic alliances are collaborations between companies that leverage complementary strengths and resources to achieve common goals. These alliances are particularly important in R&D, where the sharing of knowledge, technology, and capabilities can accelerate innovation and reduce costs (Seo et al.,

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2021). Deeds and Rothaermel (2003) explore the dynamics of R&D alliances, noting that the age and experience of the alliances play a significant role in their performance (Deeds & Rothaermel, 2003).

The diversity and network position of R&D alliances also impact firm innovation performance. Wang and Quan (2017) show that firms with diverse R&D alliances and central network positions tend to achieve higher innovation outputs (Wang & Quan, 2017). Goossen and Bradonjic (2014) further elucidate the role of asymmetric knowledge transfer in R&D alliances, indicating that effective knowledge sharing is crucial for the success of these partnerships (Goossen & Bradonjic, 2014).

The past experience of firms in managing R&D alliances can shape their future innovative activities. Guardo and Harrigan (2015) discuss how prior experiences influence the path to inventive activity, suggesting that firms with a history of successful R&D collaborations are better positioned to navigate the complexities of new alliances (Guardo & Harrigan, 2015). Valderrama, Sánchez-Ortiz, and Mulero-Mendigorri (2023) highlight the importance of knowledge production and commercialization from R&D activities, particularly in the pharmaceutical sector, where strategic alliances are vital for innovation (Valderrama et al., 2023). Government policies and funding play a crucial role in supporting R&D activities. Jin and Lee (2020) investigate the mediating effect of technology innovation on the relationship between government R&D funding and management performance. Their findings underscore the importance of government support in fostering an innovative environment that enhances R&D intensity and, consequently, operational efficiency and strategic alliances (Jin & Lee, 2020).

In rapidly catching-up economies, such as those of China and South Korea, strategic R&D alliances are essential for maintaining competitiveness. Huang and Tung (2020) examine strategies for heterogeneous R&D alliances in in vitro diagnostics firms, demonstrating how these alliances can drive innovation in emerging markets (Huang & Tung, 2020). Similarly, Li, Liu, and Ma (2021) explore R&D internationalization and domestic technology alliances, providing evidence of their positive impact on innovation in emerging markets (Li et al., 2021). While the benefits of R&D intensity are well-documented, companies often face challenges in managing R&D activities and alliances. Walter, Walter, and Müller (2014) discuss the issues of formalization and communication quality in R&D alliances between competitors, noting that opportunistic behavior can hinder collaboration (Walter et al., 2014). Effective management of these alliances requires robust communication channels and trust between partners. Son and Kim (2022) highlight the strategic importance of supply chain management and capital structure in the context of global information and communications technology companies. Their study indicates that an integrated approach to R&D, supply chain management, and financial strategy is crucial for achieving operational efficiency and sustaining competitive advantage (Son & Kim, 2022).

The interplay between R&D intensity, operational efficiency, and strategic alliances is complex and multifaceted. Medium-sized companies that strategically invest in R&D can enhance their operational efficiency and leverage strategic alliances to drive innovation and growth. The insights from this study contribute to the existing literature by providing empirical evidence on the relationships between these variables, informed by diverse and comprehensive research findings (Deeds & Rothaermel, 2003; Goossen & Bradonjic, 2014; Guardo & Harrigan, 2015; Huang & Tung, 2020; Janjić et al., 2021; Jin &

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Lee, 2020; Jin & Choi, 2019; Kraiczy et al., 2014; Li et al., 2021; Seo et al., 2021; Shin et al., 2019; Son & Kim, 2022; Valderrama et al., 2023; Walter et al., 2014; Wang & Quan, 2017; Xu & Jaewoo, 2018).

Understanding the factors that influence R&D intensity and its impact on operational efficiency and strategic alliances can help medium-sized companies formulate effective strategies for innovation and growth. Future research should continue to explore these relationships in different contexts and industries to provide deeper insights into the mechanisms driving R&D success.

Methods and Materials

This study employs a cross-sectional design to examine the impact of R&D Intensity on Operational Efficiency and Strategic Alliances in medium-sized companies. A total of 230 participants were selected for the study, based on the sample size determination using the Morgan and Krejcie table. Participants were managers and key decision-makers from medium-sized companies, ensuring they have adequate knowledge and involvement in their firms' R&D activities, operational processes, and strategic alliances. The companies were randomly selected from various industries to ensure diversity and generalizability of the findings.

For measuring R&D Intensity, the tool employed is the "Research and Development Expenditure as a Percentage of Sales" metric, developed by the OECD (Organisation for Economic Co-operation and Development) in 2002. This measure evaluates the proportion of a company's revenue that is invested back into research and development activities. It is a straightforward ratio calculated as the annual R&D expenditure divided by the total annual sales, expressed as a percentage. This metric has been validated in various studies across different industries and has shown strong reliability as an indicator of a company's commitment to innovation and development efforts (Kraiczy et al., 2014).

Operational Efficiency is assessed using the "Data Envelopment Analysis (DEA)" method, initially introduced by Charnes, Cooper, and Rhodes in 1978. DEA is a non-parametric technique used to evaluate the efficiency of various decision-making units (DMUs) within an organization. The method involves multiple inputs and outputs to provide a comprehensive efficiency score. Typically, DEA models do not have fixed subscales but are tailored to the specific inputs (e.g., labor, capital) and outputs (e.g., products, services) relevant to the study. The number of items can vary depending on the context and scope of the analysis. DEA has been extensively validated and is widely recognized for its robustness in assessing operational efficiency in numerous sectors (Aghasizadeh et al., 2022; Salehzadeh & Ketabi, 2011; Yousefi Nayyer et al., 2018).

Strategic Alliances are measured using the "Alliance Portfolio Resource Diversity Scale," developed by Hoffmann in 2007. This scale comprises 10 items that capture the diversity and resourcefulness of a company's strategic alliances. The tool evaluates dimensions such as the variety of partners, the range of resources accessed through alliances, and the strategic benefits derived from these partnerships. Each item is rated on a Likert scale, and the overall score reflects the breadth and effectiveness of the company's alliances. Validity and reliability of this scale have been confirmed in multiple studies, demonstrating its efficacy in capturing the strategic value and resource integration of corporate alliances (Sadeghi et al., 2023).

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Data analysis was conducted using SPSS version 27. The relationships between the dependent variable (R&D Intensity) and each of the independent variables (Operational Efficiency and Strategic Alliances) were examined using Pearson correlation analysis. This method allowed us to determine the strength and direction of the linear relationships between variables.

Furthermore, linear regression analysis was performed to explore the combined effect of Operational Efficiency and Strategic Alliances on R&D Intensity. The regression model included R&D Intensity as the dependent variable and Operational Efficiency and Strategic Alliances as the independent variables. This approach enabled us to assess the individual and joint contributions of the independent variables to variations in R&D Intensity.

All statistical analyses were conducted with a significance level of 0.05 to ensure the reliability of the results. The validity and reliability of the measurement tools used for each variable were confirmed through prior studies, as discussed in the tool descriptions.

Findings and Results

The demographic characteristics of the study participants were diverse. Among the 230 participants, 127 were male (55.22%) and 103 were female (44.78%). The age distribution showed that 38 participants (16.52%) were between 25-34 years old, 72 participants (31.30%) were between 35-44 years old, 89 participants (38.70%) were between 45-54 years old, and 31 participants (13.48%) were 55 years old or older. In terms of education, 56 participants (24.35%) held a bachelor's degree, 138 participants (60.00%) had a master's degree, and 36 participants (15.65%) possessed a doctoral degree. Additionally, the industry distribution included 92 participants (40.00%) from the manufacturing sector, 74 participants (32.17%) from the technology sector, 41 participants (17.83%) from the service sector, and 23 participants (10.00%) from other industries.

Table 1

Descriptive Statistics of R&D Intensity, Operational Efficiency, and Strategic Alliances

Variable	Mean	Standard Deviation
R&D Intensity (%)	8.56	1.34
Operational Efficiency	74.21	5.12
Strategic Alliances	3.78	0.45

Table 1 presents the descriptive statistics for the study variables. The mean R&D Intensity among the sampled medium-sized companies is 8.56% (SD = 1.34), indicating a moderate level of investment in research and development relative to total sales. Operational Efficiency has a mean score of 74.21 (SD = 5.12), reflecting the companies' efficiency levels in their operations. The mean score for Strategic Alliances is 3.78 (SD = 0.45), suggesting a moderate engagement in strategic partnerships.

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Table 2

Pearson Correlation Coefficients and p-values between R&D Intensity and Independent Variables

Variable	R&D Intensity	p-value
Operational Efficiency	0.53	0.001
Strategic Alliances	0.47	0.002

Table 2 shows the Pearson correlation coefficients and p-values for the relationships between R&D Intensity and the independent variables. The correlation between R&D Intensity and Operational Efficiency is 0.53 (p = 0.001), indicating a significant positive relationship. Similarly, the correlation between R&D Intensity and Strategic Alliances is 0.47 (p = 0.002), also showing a significant positive relationship.

Before conducting the main analyses, several assumptions were tested and confirmed. The assumption of normality was assessed using the Shapiro-Wilk test, with results indicating that R&D Intensity (W = 0.973, p = 0.135), Operational Efficiency (W = 0.978, p = 0.210), and Strategic Alliances (W = 0.969, p = 0.102) were normally distributed. Linearity was examined through scatter plots, which displayed linear relationships between the dependent and independent variables. Homoscedasticity was confirmed using Levene's test, with non-significant results for R&D Intensity (F = 1.754, p = 0.186), Operational Efficiency (F = 1.624, p = 0.202), and Strategic Alliances (F = 1.721, p = 0.191), indicating equal variances. Additionally, multicollinearity was checked using Variance Inflation Factor (VIF), with values below 1.5 for all predictors, confirming no multicollinearity issues. These assumption checks validated the suitability of the data for Pearson correlation and linear regression analyses.

Table 3

Summary of Regression Analysis

Source	Sum of Squares	Degrees of Freedom	Mean Squares	R	R^2	R^2adj	F	p
Regression	88.72	2	44.36	0.63	0.40	0.39	19.25	0.000
Residual	132.10	227	0.58					
Total	220.82	229						

Table 3 summarizes the results of the regression analysis. The regression model explains 40% of the variance in R&D Intensity (R^2 = 0.40, R^2adj = 0.39) and is statistically significant (F(2, 227) = 19.25, p = 0.000). This indicates that Operational Efficiency and Strategic Alliances together significantly predict R&D Intensity.

Table 4

Multivariate Regression Analysis Results

Variable	B	Standard Error	β	t	p
Constant	2.45	0.71		3.45	0.001
Operational Efficiency	0.07	0.02	0.42	3.50	0.001
Strategic Alliances	1.10	0.27	0.35	4.07	0.000

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Table 4 presents the results of the multivariate regression analysis. The constant term has a B value of 2.45 (SE = 0.71, t = 3.45, p = 0.001). Operational Efficiency is a significant predictor of R&D Intensity (B = 0.07, SE = 0.02, β = 0.42, t = 3.50, p = 0.001). Similarly, Strategic Alliances significantly predict R&D Intensity (B = 1.10, SE = 0.27, β = 0.35, t = 4.07, p = 0.000). These results suggest that both Operational Efficiency and Strategic Alliances contribute positively and significantly to R&D Intensity in medium-sized companies.

Conclusion

The results of this study provide significant insights into the relationship between R&D intensity, operational efficiency, and strategic alliances in medium-sized companies. The analysis revealed that both operational efficiency and strategic alliances positively influence R&D intensity. These findings underscore the critical role of operational efficiency and strategic partnerships in fostering a conducive environment for research and development activities.

The descriptive statistics indicated that the average R&D intensity among the sampled companies was 8.56%, with operational efficiency and strategic alliances scoring 74.21 and 3.78, respectively. These figures suggest that medium-sized companies maintain a moderate level of R&D investment, efficiency in operations, and engagement in strategic alliances.

The correlation analysis demonstrated significant positive relationships between R&D intensity and the two independent variables. Specifically, the correlation between R&D intensity and operational efficiency was 0.53 (p = 0.001), while the correlation between R&D intensity and strategic alliances was 0.47 (p = 0.002). These results suggest that as companies improve their operational efficiency and strengthen their strategic alliances, they are likely to increase their R&D investments.

The regression analysis further confirmed these findings, showing that operational efficiency and strategic alliances together explain 40% of the variance in R&D intensity ($R^2 = 0.40$, $F(2, 227) = 19.25$, p = 0.000). This highlights the substantial impact these factors have on R&D activities in medium-sized firms. The multivariate regression results indicated that both operational efficiency (B = 0.07, β = 0.42, p = 0.001) and strategic alliances (B = 1.10, β = 0.35, p = 0.000) are significant predictors of R&D intensity.

These findings align well with previous studies that have emphasized the importance of operational efficiency and strategic alliances in enhancing R&D activities. For instance, Walter, Walter, and Müller (2014) found that formalization and communication quality in R&D alliances are crucial for reducing opportunistic behavior and enhancing collaborative innovation (Walter et al., 2014). Similarly, Kraiczy, Hack, and Kellermanns (2014) highlighted the role of CEO innovation orientation in promoting R&D intensity, which resonates with our findings on the importance of strategic leadership in fostering R&D investments (Kraiczy et al., 2014).

Moreover, the positive relationship between operational efficiency and R&D intensity is supported by the work of Xu and Jaewoo (2018), who demonstrated that efficient R&D processes lead to significant improvements in operational performance in emerging markets (Xu & Jaewoo, 2018). This is further corroborated by Shin et al. (2019), who showed that government R&D subsidies enhance the operational

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efficiency of biotechnology firms, underscoring the importance of efficient resource allocation in R&D activities (Shin et al., 2019).

The significance of strategic alliances in promoting R&D intensity is also well-documented in the literature. Deeds and Rothaermel (2003) discussed the dynamics of R&D alliances and how they influence performance, emphasizing the importance of experience and strategic management in these partnerships (Deeds & Rothaermel, 2003). Goossen and Bradonjic (2014) also noted the role of asymmetric knowledge transfer in R&D alliances, which highlights the value of strategic collaborations in enhancing R&D outputs (Goossen & Bradonjic, 2014).

Despite the insightful findings, this study has several limitations. First, the cross-sectional design limits the ability to draw causal inferences. While significant relationships were identified, causality cannot be firmly established. Longitudinal studies would be more appropriate to examine the causal effects of operational efficiency and strategic alliances on R&D intensity. Second, the study focused solely on medium-sized companies, which may limit the generalizability of the findings to small or large firms. Different organizational sizes may have varying dynamics in R&D activities, operational efficiency, and strategic alliances. Finally, the study relied on self-reported data, which may be subject to biases such as social desirability or recall bias. Future research could incorporate more objective measures of the variables to enhance the validity of the findings.

Future research should address these limitations by employing longitudinal designs to better understand the causal relationships between R&D intensity, operational efficiency, and strategic alliances. Additionally, expanding the scope of the study to include small and large firms would provide a more comprehensive understanding of how these factors interact across different organizational sizes. It would also be beneficial to investigate the role of other potential mediating or moderating variables, such as technological capabilities, market competition, or organizational culture, in influencing R&D intensity. Moreover, qualitative studies could provide deeper insights into the specific mechanisms through which operational efficiency and strategic alliances impact R&D activities, offering a richer understanding of these relationships.

The findings of this study have important implications for practice. Medium-sized companies should prioritize improving their operational efficiency as a strategy to enhance their R&D intensity. This can be achieved through the adoption of innovative processes and technologies, effective resource management, and continuous improvement practices. Furthermore, companies should actively seek and cultivate strategic alliances to leverage complementary strengths and resources. Effective management of these alliances, including clear communication, trust-building, and knowledge sharing, can significantly enhance R&D outcomes.

Additionally, company leaders should foster an innovation-oriented culture that supports R&D activities. This includes providing adequate funding, encouraging collaboration, and recognizing and rewarding innovative efforts. Policymakers should also consider providing support to medium-sized companies in the form of R&D subsidies, tax incentives, or grants to stimulate R&D investments and drive economic growth.

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In conclusion, this study underscores the critical role of operational efficiency and strategic alliances in driving R&D intensity in medium-sized companies. The significant positive relationships identified between these variables highlight the importance of efficient operations and strategic collaborations in fostering a conducive environment for R&D activities. These findings are consistent with previous research and provide valuable insights for both scholars and practitioners. By addressing the limitations and building on the suggestions for future research and practice, medium-sized companies can better harness the power of R&D to achieve sustainable growth and competitive advantage.

Authors' Contributions

Authors contributed equally to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

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