R&D Expenditures and Firm Performance of Plantation Firms Listed on the Indonesia Stock Exchange (IDX), 2019–2023

Pengeluaran R&D dan Kinerja Perusahaan Perkebunan yang Terdaftar di Bursa Efek Indonesia (BEI), 2019–2023

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Abstract This study investigates the impact of R&D expenditure and firm characteristics on the financial performance of Indonesian plantation companies listed on the Indonesia Stock Exchange (IDX) from 2019 to 2023, using quantile regression analysis. Return on Equity (ROE) serves as the performance metric across the 25th, 50th, and 75th quantiles. The results show that R&D expenditure has a significantly negative effect at the median quantile, while Debt to Equity Ratio (DER) negatively affects ROE at both lower and median quantiles. Capital Intensity and Firm Size do not show significant effects, whereas Firm Age has a slight positive effect in the upper quantile. These findings suggest that while R&D investments may burden short-term profitability, they remain essential for long-term performance if managed strategically. The study highlights the importance of partnerships with credible R&D institutions, technological adoption, and government support to overcome sector-specific limitations. Limitations include the sector-specific focus and lack of qualitative dimensions, indicating the need for broader and mixed-method research in the future. Moreover, given the five-year observation period and limited sample size, the findings should be interpreted cautiously and are not intended to be generalized beyond the observed context.

Keywords*:* Debt to Equity Ratio, Firm Characteristics, Plantation Firms, R&D expenditure, Return on Equity

Abstrak Penelitian ini menganalisis pengaruh pengeluaran R&D dan karakteristik perusahaan terhadap kinerja keuangan perusahaan perkebunan Indonesia yang terdaftar di Bursa Efek Indonesia (BEI) selama periode 2019 hingga 2023 dengan menggunakan analisis regresi kuantil. *Return on Equity* (ROE) digunakan sebagai indikator kinerja pada kuantil ke-25, ke-50, dan ke-75. Hasil penelitian menunjukkan bahwa pengeluaran R&D memiliki pengaruh negatif yang signifikan pada kuantil median, sementara *Debt to Equity Ratio* (DER) berpengaruh negatif terhadap ROE pada kuantil bawah dan median. *Capital Intensity* dan Ukuran Perusahaan tidak menunjukkan pengaruh yang signifikan, sedangkan Umur Perusahaan memberikan pengaruh positif kecil pada kuantil atas. Temuan ini menunjukkan bahwa meskipun investasi R&D dapat membebani profitabilitas jangka pendek, investasi tersebut tetap penting untuk kinerja jangka panjang jika dikelola secara strategis. Studi ini menekankan pentingnya kemitraan dengan lembaga R&D yang kredibel, adopsi teknologi, dan dukungan pemerintah untuk mengatasi keterbatasan sektoral. Keterbatasan studi ini mencakup fokus sektoral dan tidak digunakannya pendekatan kualitatif, sehingga diperlukan penelitian lanjutan dengan pendekatan yang lebih luas dan metode campuran. Selain itu, mengingat periode observasi yang hanya lima tahun dan ukuran sampel yang terbatas, temuan penelitian ini sebaiknya ditafsirkan secara hati-hati dan tidak dimaksudkan untuk digeneralisasi di luar konteks yang diamati.

Kata Kunci*:* Debt to Equity Ratio, Karakteristik Perusahaan, Pengeluaran R&D, Perusahaan Perkebunan, Return on Equity

Penulis yang tidak disertai dengan catatan kaki instansi adalah peneliti pada Pusat Penelitian Kelapa Sawit

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INTRODUCTION

Small and medium-sized plantation firms in Indonesia, constituting a significant portion of the industry, frequently encounter financial and technical constraints that limit their R&D utilization. These challenges include limited access to research expertise, suboptimal infrastructure, and insufficient working capital, all of which inhibit innovation capacity. Intan *et al.* (2024) found that among agricultural firms listed on the Indonesia Stock Exchange between 2015 and 2021, internal factors like firm growth had a positive impact on profitability (ROA), while debt-to-asset ratio (DAR) and exchange rate volatility had significantly negative effects. This underscores how financial instability and capital constraints can hamper firms' ability to invest in innovation and adopt new technologies.

Metrics such as Return on Equity (ROE), Return on Assets (ROA), and Gross Profit Margin (GPM) are widely adopted in both academic research and industry practice to assess financial performance (Jaunanda *et al*., 2024). ROE, in particular, provides a clear picture of how effectively shareholder capital generates net income, making it an essential metric in managerial decision-making.

In the Indonesian context, particularly in the plantation sector encompassing palm oil, rubber, coffee, and cocoa, ROE remains a critical measure of equity efficiency under volatile conditions. Empirical evidence from plantation subsector firms listed on the Indonesia Stock Exchange (2016–2021) shows that capital structure, as proxied by DER, exerts no significant influence on stock returns, pointing to a muted market reaction to leverage strategies (Silver, 2023).

However, broader agribusiness studies reveal a different facet: DER appears to undermine operational effectiveness, with higher leverage correlating negatively with ROA (Suluh, 2025). This suggests that, even if debt does not immediately influence market valuation, it may still impair asset efficiency, highlighting latent vulnerabilities in managerial and structural optimization within plantation firms.

Challenges faced by Indonesian plantation firms stem not only from global factors such as weather dependency, international market pressures, and sustainability demands (FAO, 2020) but also from domestic constraints. These include strict regulatory frameworks, limited access to affordable financing, and relatively low investment in research and development (R&D) compared to regional competitors like Malaysia (WIPO, 2021). In such an environment, the ability to innovate is no longer an optional advantage but a strategic necessity for maintaining competitiveness and long-term financial performance.

R&D expenditure is broadly acknowledged as a pivotal driver of long-term productivity and innovation in agriculture. Empirical evidence shows that both domestic and foreign agricultural R&D significantly boost total factor productivity (TFP), with domestic R&D making a particularly strong contribution (Adetutu & Ajayi, 2020). In the plantation sector, this translates into advancements such as the development of superior crop varieties, precision fertilization systems, and satellite-based land monitoring technologies. However, due to the lengthy biological production cycles inherent in plantations, the financial benefits of R&D often emerge over extended time horizons. Moreover, Rawat and Akter (2020) highlight that volatility in public-sector R&D funding, especially prevalent in lower-middle-income countries, can hinder the sustainable adoption and implementation of such innovations.

Alam *et al*. (2020) highlighted that the effectiveness of R&D investment is not uniform across industries, particularly in emerging markets. In high-technology sectors, R&D activities often translate into quick financial returns due to faster innovation cycles and responsive market dynamics. In contrast, sectors like agriculture and plantations face significant delays in realizing the benefits of innovation due to natural production cycles, extended field testing, and regulatory constraints. These structural conditions result in a trade-off between innovation-driven growth and short-term profitability, a challenge that is more pronounced for firms operating with limited financial flexibility.

Small and medium-sized plantation firms in Indonesia, representing a substantial share of the industry, face considerable financial and technical constraints that limit their capacity to fully leverage R&D outcomes. Challenges such as restricted access to expert researchers, infrastructure gaps, and insufficient working capital impede innovation adoption. However, recent empirical studies suggest

promising avenues through structured partnerships. For example, collaborative models between industry and R&D institutions, especially when involving universities and government agencies, can help pool resources, de-risk innovation, and improve implementation outcomes (Nurzal & Rosadi, 2024).

Empirical evidence shows that plantation firms actively engaged in R&D are better equipped to address global challenges such as climate change, pest outbreaks, and crop diseases. Innovations in genetic breeding, data-driven agronomic management, and satellite-based land monitoring have been proven to enhance productivity and resource efficiency. However, R&D intensity in Indonesia's plantation sector remains low due to funding shortages, weak institutional collaboration, and policy barriers that slow technology commercialization (WIPO, 2021). These conditions suggest that without targeted strategies, the full potential of R&D to improve financial performance may remain untapped.

Given these circumstances, it is important to conduct a comprehensive analysis of how R&D expenditure influences financial performance, particularly ROE, in Indonesian plantation firms. Furthermore, firm-specific characteristics such as capital intensity, firm size, firm age, and capital structure are also likely to contribute to variations in profitability. This study aims to examine the effects of R&D expenditure and these firm characteristics on ROE across different performance levels using quantile regression. The findings are expected to provide evidence-based recommendations for both industry practitioners and policymakers on how to optimize R&D investments to achieve sustainable profitability in the plantation sector.

MATERIALS & METHODS

This study identifies several key variables relevant for evaluating firm performance in the agricultural and plantation subsector in Indonesia. The selection of these variables is grounded in both empirical findings and theoretical frameworks drawn from established literature. ROE is employed as the primary indicator of firm profitability, as proposed by Tung & Binh (2021). ROE reflects a firm's ability to efficiently utilize its equity to generate profits and serves as a critical metric for stakeholders. It is commonly used by management to assess capital efficiency, benchmark performance against competitors, and identify operational areas for improvement.

R&D expenditure is included based on the framework by Dai *et al*. (2020), who emphasize its central role in fostering innovation and long-term growth. In the agricultural sector, R&D is particularly relevant for driving technological advancements, such as the development of new crop varieties or advanced irrigation systems, which in turn enhance both competitiveness and operational efficiency.

Capital Intensity (CIT), representing the firm's fixed asset structure, is also included due to its influence on productivity, as noted by Sinha *et al.* (2019). CIT serves as an important measure for evaluating investment in fixed assets like machinery and infrastructure, which can inform more effective capital allocation strategies.

Firm size, as measured by number of employees (EMP), represents a firm's operational scale and resource capacity. Empirical studies generally support the notion that larger firms are better equipped to pursue innovation due to greater resource pools and economies of scale. For instance, research on small businesses found that larger firms tend to invest more resources in innovation initiatives, consistent with Schumpeterian theory that scale enables firms to sustain innovation investments (Marom, 2019).

Firm Age (AGE) reflects a firm's experience in navigating market dynamics. As discussed by Tung & Binh (2021), firm age provides insights into adaptability and risk management capacity. Older firms may leverage accumulated experience to strengthen their reputations and build strategic partnerships, thereby promoting greater business stability.

The Debt to Equity Ratio (DER) serves as a proxy for a firm's capital structure, which influences financial flexibility in supporting innovation, as noted by Tomori *et al.* (2022). DER is also relevant for managing financial risk. Firms with high leverage may need to adjust their financing strategies to reduce debt burdens and support more sustainable investment decisions.

Prior research by Dhita *et al*. (2018) suggests that an optimal capital structure can improve profitability, whereas excessively high DER levels increase the risk of financial distress. In this study, these variables are

examined to assess whether capital structure, as proxied by DER, is influenced by R&D expenditure and how this relationship manifests in firm performance, as measured by ROE.

This study examines the influence of R&D expenditure and firm-specific characteristics on the financial performance of plantation firms in Indonesia. The analysis focuses on three main aspects: the effect of R&D expenditure on firm performance as measured by Return on Equity (ROE); the contribution of firm characteristics, such as capital intensity, firm size, firm age, and debt to equity rasio, to variations in ROE; and the identification of strategic approaches that can enhance the effectiveness of R&D investments in improving competitiveness and ensuring long-term sustainability.

The theoretical foundation of this study is based on the Resource-Based View (RBV), which posits that sustainable competitive advantage stems from the effective management of valuable, rare, and inimitable internal resources, including R&D activities. This framework is supported by prior empirical findings that emphasize the strategic value of firm-specific capabilities in driving performance. The analysis is further enriched by the updated Open Innovation framework, which emphasizes that innovation is no longer confined within organizational boundaries but thrives through strategic collaborations with external entities. Chesbrough *et al*. (2014) describe open innovation as a distributed and purposefully managed process involving knowledge flows across organizational borders, aligned with the firm's business model. This modern interpretation highlights the potential for plantation firms to enhance innovation outcomes by integrating external expertise from universities, research institutions, and industry partners, thus overcoming internal capacity limitations.

By combining RBV and Open Innovation perspectives, this study adopts a comprehensive lens to understand how plantation firms can optimize the impact of R&D investments. This integrative framework supports the identification of internal and external factors that influence innovation outcomes and provides insights into navigating the complex and dynamic conditions of the plantation sector.

Based on the theoretical framework and prior empirical findings, this study hypothesizes that R&D expenditure has a significantly negative effect on ROE in the median quantile. This is consistent with evidence indicating that, in sectors with long innovation cycles such as agriculture, R&D investments often require extended time horizons to generate positive returns. This view aligns with Pray & Fuglie (2015), who identified capital constraints and shortages of skilled labor as key barriers to adopting new technologies in the agricultural sector.

DER is hypothesized to exert a significantly negative effect on ROE, particularly among low- and mid-performing firms, as high leverage increases liquidity risk and reduces financial flexibility. This hypothesis is supported by Alter and Elekdag (2016), who analyzed corporate leverage in emerging markets and found that elevated debt levels constrained firms' financial resilience and heightened their vulnerability to external financial shocks.

Conversely, variables such as EMP and CIT are expected to exert no significant influence on ROE, consistent with the findings of Sinha et al. (2019), who argued that fixed asset intensity and operational scale have limited direct relevance to profitability in agriculture-driven industries.

Firm age (AGE) is hypothesized to exert a positive effect on financial performance, particularly for mature, high-performing firms, reflecting long-term learning and stability. While literature on this relationship remains mixed, reviews indicate that firm age often correlates positively with performance up to a certain point, due to accumulated experience and organizational routines (Rossi, 2016).

With these hypotheses, this study aims to explore how R&D expenditure, DER, EMP, and AGE collectively influence financial performance within Indonesia's plantation sector. The goal is to derive insights that can guide strategic efforts toward enhancing productivity and sustainability in this industry.

This research adopts a quantitative approach using panel data covering the 2019–2023 period. The population consists of firms in the agricultural and plantation sectors listed on the Indonesia Stock Exchange (IDX) during the study period. Data were obtained from official and publicly accessible sources, including annual financial statements published on the IDX website (www.idx.co.id) and the firms' official websites. To provide contextual depth, complementary information was also drawn from reputable

international institutions such as the World Intellectual Property Organization (WIPO) and the Food and Agriculture Organization (FAO).

During the data screening process, not all firms meeting the initial population criteria were included in the final analysis due to several limitations. First, some firms lacked complete financial statement data for the full five-year period from official sources. Second, certain firms changed their sector or subsector classifications, making them no longer relevant to the agricultural and plantation categories. Sector and subsector classifications were verified based on disclosures in financial statements available on the IDX platform.

After applying these criteria, 21 firms were selected as the final sample. These firms consistently operated within the agricultural and plantation sectors throughout the research period and had complete data available. The selected firms, identified by their ticker symbols, are AALI, ANDI, ANJT, UNSP, CSRA, DSNG, BWPT, FAPA, GZCO, JAWA, LSIP, MGRO, PNGO, PGUN, SIMP, SGRO, SSMS, SMAR, STAA, TLDN, and TAPG.

The Quantile Regression method was employed as the primary analytical approach to address the issue of non-normal data distribution. Normality testing using the Shapiro–Wilk test revealed that most variables, including the dependent variable ROE and the independent variables R&D, CIT, EMP, AGE, and DER, did not satisfy normality assumptions, even after logarithmic transformation. This indicates that traditional methods such as Ordinary Least Squares (OLS) regression are less suitable, as their assumptions regarding residual normality and robustness to outliers are not met. The Quantile Regression model can be formulated as follows:

$$Q\_y(\tau \mid X) = \beta 0(\tau) + \beta 1(\tau) \cdot R\&D + \beta 2(\tau) \cdot CIT + \beta 3(\tau) \cdot EMP + \beta 4(\tau) \cdot AGE + \beta 5(\tau) \cdot DER + \epsilon(\tau)$$

The operational definitions of the variables in the model are as follows:

- Return on Equity (ROE) is the ratio of net profit to total equity, used as an indicator of a firm's financial performance (profitability). In this study, ROE is expressed as a percentage (%).
- Research and Development Expenditure (R&D) refers to firms spending on research and development activities. This information is obtained from the “Research and Development” or “Innovation Expense” item in the annual financial statements and is expressed in millions of rupiah.
- Capital Intensity (CIT) is the ratio of fixed assets to total assets (%), representing the firm's asset structure. A higher CIT indicates a greater proportion of investment in fixed assets, such as factories, equipment, and infrastructure.
- Firm Size (EMP) refers to the number of employees at the end of each year, measured in persons. This variable reflects the scale of a firm's operations.
- Firm Age (AGE) is the number of years since a firm's establishment, calculated from the year it was founded to the year under observation. Firm age reflects operational experience and potential business stability.
- Debt to Equity Ratio (DER) is the ratio of total liabilities to total equity, expressed as a multiple (times). DER serves as an indicator of capital structure.

The term $Qy(\tau \mid X)$ represents the τ-th quantile of the dependent variable (ROE), conditioned on the independent variables X. In this study, quantiles are determined based on the distribution of ROE values across the sample firms during the observation period. The lower quantile (25th) represents firms with ROE in the bottom 25% of the distribution, the median quantile (50th) represents firms in the middle range, and the upper quantile (75th) represents firms with ROE in the top 25%. Because the dataset covers multiple years (2019–2023), a single firm may appear in different quantiles in different years, depending on its annual ROE performance. This dynamic classification reflects the time-series nature of the data and justifies the use of panel quantile regression, as it captures variations in firm performance over time rather than fixing each firm to a single quantile category for the entire period.

The intercept, $\beta_0(\tau)$, for the τ-th quantile indicates the predicted ROE value when all independent variables are zero. This intercept can vary across quantiles, reflecting the unique dynamics of the

ROE distribution at different levels. The coefficients $\beta 1(\tau), \beta 2(\tau), ..., \beta 5(\tau)$ represent the regression coefficients at the τ-th quantile, showing the magnitude of the influence of each independent variable on ROE at that quantile. These coefficients are not constant and can change depending on the quantile being analyzed, enabling deeper insights into the data distribution.

Finally, the error term $\in(\tau)$ for the τ-th quantile represents the deviation between the observed value and the predicted value at that quantile. Together, these components facilitate a detailed understanding of how independent variables affect ROE across different parts of its distribution.

Quantile regression is estimated at three main quantile points: the 25th quantile (0.25) representing low-performing firms, the 50th quantile (0.50 or median) representing medium-performing firms, and the 75th quantile (0.75) representing high-performing firms. These quantiles were chosen because they represent the lower, middle, and upper segments of the ROE distribution, thereby providing a comprehensive view of how the influence of variables differs across performance levels. By analyzing these three quantiles, the study can determine whether factors such as R&D expenditure and DER have varying impacts on less profitable firms compared to highly profitable ones. This approach is also widely used because quartiles (first, median, and third) facilitate interpretation as “low,” “medium,” and “high” performance groups.

RESULTS & DISCUSSION

Quantile regression analysis provide in-depth insight into the influence of each independent variable on ROE at various levels of company performance. Quantile regression analysis was performed at the 25th quantile (low), 50th quantile (medium), and 75th quantile (high), which was used to evaluate the influence of R&D and other variables on ROE at different levels of company performance. The estimated coefficients and their significance values are shown in Tables 1 and 2 below.

Table 1. Quantile Regression Coefficients
Tabel 1. Koefisien Regresi Kuantil

Variable	Q25 Coefficients	Q50 Coefficients	Q75 Coefficients
C	15.04996	24.35739	19.75858
R&D	-12.13635	-13.20478	-12.22435
CIT	-0.021332	-0.024702	-0.012776
EMP	0.000371	0.000320	0.000117
AGE	-0.165696	-0.189876	0.061222
DER	-0.084607	-0.086397	-0.035089

Table 2. P- Value Quartile Regression
Tabel 2. Regresi Kuartil Nilai-P

Variable	Q25 P- value	Q50 P- value	Q75 P- value
C	0.1750	0.0322	0.0360
R&D	0.1796	0.0495	0.3689
CIT	0.6658	0.6532	0.6625
EMP	0.1870	0.2692	0.7131
AGE	0.1301	0.2239	0.7965
DER	0.0000	0.0000	0.6775

The quantile analysis revealed that the effect of each variable on ROE varied across different levels of firm financial performance. Three main quantiles were analyzed: the lower quantile (τ = 0.25), the median quantile (τ = 0.50), and the upper quantile (τ = 0.75). The results and interpretation are divided into three subsections based on the observed quantiles.

1. Lower Quantile (τ = 0.25)

In the lower quantile, DER showed a significant negative effect (-0.084607), indicating that a high debt structure posed a major barrier to profitability for low-performing firms. This finding aligns with Alter and Elekdag (2016), who emphasized that excessive leverage in emerging markets not only exacerbates liquidity pressures but also undermines profitability by increasing financial fragility—especially during periods of tightening global financial conditions.

R&D expenditure also recorded a negative coefficient (-12.13635) but was not statistically significant, suggesting that smaller and underperforming firms encountered challenges in realizing returns from innovation efforts. This is consistent with Pray and Fuglie (2015), who noted that limited capital, a shortage of skilled labor, and inadequate public policy support were persistent barriers to technology adoption in the agricultural sector.

2. Median Quantile (τ = 0.50)

At the median quantile, DER remained significantly negative (-0.086397), underscoring the importance of prudent debt management in maintaining financial stability at this performance level. CIT and EMP remained insignificant, indicating that firms in this tier had yet to optimize the utilization of fixed assets and their workforce. This is consistent with FAO (2020), which reports that many SMEs in Indonesia's agricultural sector struggle to fully utilize assets due to limited working capital and restricted access to modern technologies. Interestingly, R&D expenditure became statistically significant at this quantile (p = 0.0495), but its coefficient remained negative. This suggests that, for medium-performing firms, R&D investments begin to influence ROE but may still exert downward pressure in the short term due to high upfront costs and the long adoption cycle of innovations.

3. Upper Quantile (τ = 0.75)

In the upper quantile, DER remained negatively associated (-0.035089) with performance but lost

statistical significance, suggesting that high-performing firms might be more adept at managing leverage. AGE exhibited a minor positive effect (0.061222), supporting Boiko's (2022) finding that older firms tend to benefit from enhanced financial stability. However, R&D expenditure continued to exert a negative influence (-12.22435) on short-term profitability. This aligns with the insights of Alam *et al*. (2020), who found that in emerging economies, the impact of R&D on firm performance is often moderated by institutional factors such as investor protection and corporate governance quality. Consequently, even leading firms may struggle to convert R&D investments into immediate returns under weak institutional frameworks.

CIT showed a small, negative, and statistically insignificant coefficient across all quantiles, suggesting that plantation firms in Indonesia have yet to fully optimize their fixed capital for operational efficiency. Even though R&D-driven technologies, such as mechanization or digital monitoring systems, hold potential, their effectiveness is constrained when implementation infrastructure and investment consistency are lacking. As Rawat and Akter (2020) underscore, unstable public R&D funding combined with policy misalignment and institutional barriers can impede the realization of productivity gains from fixed capital investments.

Similarly, EMP remained insignificant across all quantiles, implying that the number of employees alone does not translate into higher productivity. Instead, workforce development through continuous training and technology adoption remains essential, as highlighted by Qorri *et al*. (2024), who emphasized the role of strategic HR management and labor-saving technologies in improving agricultural productivity.

These findings reinforce Budhidharma et al. (2023), who emphasized the importance of financial risk management in preventing liquidity pressures that may arise from R&D expenditures. The case of Wilmar Internasional, although not directly comparable due to its multinational structure, illustrates that well-managed R&D can yield substantial efficiency gains, with its 2020 Sustainability Report noting up to a 25% improvement through IoT-based land monitoring and management technologies. This demonstrates the long-term potential of strategically managed R&D to enhance competitiveness in the plantation sector..

To assess the suitability of the quantile regression model, table 3 presents the Pseudo R-squared, Adjusted R-squared, and Quasi-Likelihood Ratio (LR) statistics along with their probability values. The highly significant Prob(Quasi-LR stat) values ($p < 0.01$) at all three quantiles indicate that the overall model is appropriate for explaining variations in ROE among the observed plantation firms.

Table 3. Important Components of Quartile Regression
Tabel 3. Komponen Penting Regresi Kuartil

Component	Q25 (t = 0.25)	Q50 (t = 0.50)	Q75 (t = 0.75)
Pseudo R- squared	0.435290	0.199553	0.120736
Adjusted R- squared	0.406769	0.159127	0.076329
SE of Regression	30.04284	28.84352	32.07365
Quasi -LR Statistics	121.3459	44.22532	26.07748
Prob (Quasi -LR stat)	0.000000	0.000000	0.000000

This three-quantile analysis reveals an important dynamic: DER consistently shows a significant negative effect at low to medium performance levels, emphasizing that maintaining a healthy capital structure is a crucial prerequisite for firms to improve profitability. R&D expenditure has a significant negative effect at the median quantile, indicating the short-term costs that firms incur when investing in innovation before results are realized. At very high performance levels, the effect of R&D subsides and becomes insignificant, possibly indicating that leading firms have passed the tipping point where innovation investments begin to yield results, or at least are no longer detrimental.

Meanwhile, CIT, EMP, and AGE remain insignificant across all three quantiles, suggesting that these factors, individually, are not direct determinants of ROE in the plantation sector. This does not imply their unimportance; rather, the impact of capital intensity and workforce size may be mediated through other variables such as technology adoption and employee productivity, which are not directly measured in the model. Similarly, firm age may exert its influence through managerial or organizational culture aspects that are also not captured by this quantitative model.

These results align with the holistic view that improving firm performance cannot rely on a single factor but requires a combination of mutually reinforcing elements. For example, R&D expenditure, capital intensity, and firm size should create synergies to drive innovation and efficiency. However, the success of these synergies is strongly influenced by how the firm manages leverage (DER) and financial risk. Budhidharma *et al*. (2023) emphasized that an integrated approach to managing internal factors was necessary to prevent performance decline and financial distress. In the context of these findings, firms that can balance R&D investment with prudent debt management tend to be more successful in achieving sustainable performance improvements. Conversely, without proper risk management, innovation costs can become a burden rather than a benefit.

Therefore, the plantation sector's business strategy needs to include optimizing the combination of inputs (capital, labor, technology) while ensuring a robust financial structure so that innovation-driven performance improvements are not hindered by liquidity or solvency issues.

CONCLUSION

This study finds that R&D expenditure and capital structure are important but complex determinants of plantation firm performance, as measured by ROE. R&D expenditure shows a significant negative effect in the short term for medium-performing firms, indicating a trade-off between innovation investment and immediate profitability. DER has a significant negative impact on low and medium performing firms, highlighting that excessive leverage hinders profitability. For high performing firms, the effect of DER becomes insignificant, suggesting better debt management capability. Other firm characteristics, capital intensity, size, and age, do not significantly influence ROE across quantiles, implying that without effective management and strategic direction, large asset bases or firm size alone do not guarantee superior performance.

Firm-level implications:

1. R&D Planning : Plantation firms should plan R&D investments prudently. While innovation is critical for long-term competitiveness, management must account for its potential short-term cost impact. Collaborating with credible external research institutions and universities can improve R&D efficiency by leveraging existing expertise and infrastructure without incurring the full cost.
2. Capital Structure & Risk Management : Given the adverse effect of high DER, firms should maintain optimal leverage by controlling debt growth, prioritizing internal financing for strategic projects, and restructuring liabilities to reduce financing costs. Building financial buffers ensures that critical investments, including R&D, are not disrupted by liquidity constraints. Operational efficiency improvements. through employee training in modern agronomic techniques and better utilization of fixed assets, can enhance productivity without necessarily increasing labor size.
3. Policy implications : The government can support innovation in the plantation sector by offering tax incentives for R&D, simplifying licensing for agricultural innovation projects, and increasing funding for applied research collaborations

between firms and research institutions. Super deduction tax schemes, if simplified and widely accessible, could encourage greater R&D investment. Establishing research consortia among plantation firms can further reduce innovation costs and risks, while strengthening sector-wide competitiveness.

This study finds that R&D expenditure has a significantly negative effect on Return on Equity (ROE) at the median quantile, while the Debt to Equity Ratio (DER) negatively affects ROE at both lower and median quantiles. Other firm characteristics, such as capital intensity, size, and age, do not show significant effects across performance levels. These results suggest that R&D investment may reduce short-term profitability, but it remains critical for long-term value creation when combined with sound financial governance.

This study is limited to Indonesian plantation firms, so findings may not be generalizable to other sectors. Moreover, given the five-year observation period and the relatively small sample size, the findings should be interpreted cautiously and are not intended to be generalized beyond the studied context. Future studies should explore manufacturing or technology sectors to compare patterns of influence. Extending the observation period beyond 2023 would allow examination of emerging trends, such as digital transformation in agribusiness or post-pandemic market shifts. Incorporating qualitative methods, such as deep interviews or case studies, could reveal the organizational and managerial factors that influence R&D effectiveness. Additionally, including external variables such as commodity prices, global market dynamics, and regulatory changes would provide a more comprehensive analysis.

R&D investment remains a strategic driver for long-term performance in the plantation sector, but it must be coupled with sound financial management and effective implementation strategies. Synergy between firms, research institutions, and policymakers can build an innovation ecosystem that enhances productivity, sustainability, and inclusive economic growth in Indonesia.

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