

Complex Asset Intensity and its Effects on the Readability and Tone of the Explanatory Notes of Companies Listed on B3

Intensidade de Ativos Complexos e seus Efeitos na Legibilidade e no Tom das Notas Explicativas de Empresas Listadas na B3

Intensidad de Activos Complejos y sus Efectos en la Legibilidad y el Tono de Las Notas Explicativas de las Empresas que Cotizan En B3

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Resumo: Este estudo tem como objetivo analisar os efeitos da intensidade de ativos complexos, especificamente de ativos biológicos e intangíveis, sobre a legibilidade e o tom das notas explicativas de companhias brasileiras listadas na B3. As notas explicativas foram coletadas por meio de raspagem de dados, de forma automatizada, assim como a conversão para texto, padronização e limpeza, através da linguagem *Python*. As métricas para legibilidade e tom foram calculadas a partir dos índices *Flesch* e *Fog*. Os resultados apontaram para uma associação positiva da intensidade de ativos biológicos com a legibilidade. Quanto ao tom, verificou-se o contrário, ou seja, a intensidade de intangíveis se mostrou relacionada a um tom menos positivo, especialmente em empresas mais alavancadas, sinalizando que complexidade informacional e estrutura de capital podem intensificar os efeitos sobre as informações divulgadas. Os resultados indicam que as previsões e a intensidade de ativos biológicos e intangíveis não representam fatores que influenciam negativamente a legibilidade das notas explicativas divulgadas, o mesmo não ocorrendo em relação ao tom das notas explicativas. Os resultados obtidos e a metodologia adotada no presente estudo contribuem para o aprofundamento do conhecimento acerca do conjunto de ativos analisados, ao investigar como a intensidade de ativos biológicos e intangíveis se associa à legibilidade e ao tom das notas explicativas.

Palavras-chave: Ativos Biológicos. Ativos Intangíveis. Legibilidade e Tom das Notas Explicativas.

Abstract: This study aims to analyze the effects of the intensity of complex assets, namely biological and intangible assets, on the readability and tone of explanatory notes of Brazilian companies listed on B3. The explanatory notes were collected through automated data scraping, as well as text conversion, standardization, and cleaning using *Python*. Readability and tone metrics were calculated using the *Flesch* and *Fog* index. The results indicated a positive association between biological asset intensity and readability. Regarding tone, the opposite was found, that is, the intensity of intangibles was related to a less positive tone, especially in more leveraged companies, indicating that informational complexity and capital structure can intensify the effects on the information disclosed. The results indicate that the forecasts and intensity of biological and intangible assets do not represent factors that negatively influence the readability of the explanatory notes disclosed, the same not occurring in relation to the tone of the

explanatory notes. The results obtained and the methodology adopted in this study contribute to deepening knowledge about the set of assets analyzed, by investigating how biological and intangible asset intensity is associated with the readability and tone of explanatory notes.

Keywords: *Biological Assets. Intangible Assets. Readability and Tone of Explanatory Notes.*

Resumen: *Este estudio tiene como objetivo analizar los efectos de la intensidad de los activos complejos, concretamente de los activos biológicos e intangibles, sobre la legibilidad y el tono de las notas explicativas de las empresas brasileñas cotizadas en B3. Las notas explicativas se recopilieron mediante el raspado automatizado de datos, así como mediante la conversión, estandarización y limpieza de texto con Python. Las métricas de legibilidad y tono se calcularon utilizando los índices Flesch y Fog. Los resultados indicaron una asociación positiva entre la intensidad de activos biológicos y la legibilidad. En cuanto al tono, se observó lo contrario: la intensidad de activos intangibles se relacionó con un tono menos positivo, especialmente en empresas con mayor apalancamiento, lo que indica que la complejidad informativa y la estructura de capital pueden intensificar los efectos sobre la información divulgada. Los resultados indican que las provisiones y la intensidad de activos biológicos e intangibles no representan factores que influyan negativamente en la legibilidad de las notas explicativas divulgadas, pero no ocurre lo mismo con el tono de las mismas. Los resultados obtenidos y la metodología adoptada en este estudio contribuyen a profundizar nuestra comprensión del conjunto de activos analizados, al investigar cómo la intensidad de los activos biológicos e intangibles se asocia con la legibilidad y el tono de las notas explicativas.*

Palabras clave: *Activos Biológicos. Activos Intangibles. Legibilidad y Tono de las Notas Explicativas.*

Introduction

The present study examines the effects of the intensity of biological assets and intangible assets on the readability and tone of the notes to the financial statements of Brazilian companies listed on B3 S.A. – Brasil, Bolsa, Balcão, considering the moderating effect of financial leverage. The theoretical foundation for these asset categories is based on the studies of Elad (2004), Argilés et al. (2011), Umar et al. (2022), Silva and Nardi (2023), Moura et al. (2014), Pacheco and Rover (2021), and Filho et al. (2024).

Disclosure theory suggests that information quality influences users' behavior and plays a fundamental role in reducing information asymmetry between managers and investors (Verrecchia, 2001). Among the three principal approaches to disclosure theory—association, discretion, and efficiency—the present study adopts the association-based approach, which empirically examines the relationships between accounting variables and disclosure characteristics, such as readability and tone, to infer patterns that reveal the impact of disclosure on information quality (Verrecchia, 2001).

Readability refers to the ease with which texts can be read and interpreted and is considered a fundamental element of effective corporate transparency (Ertugrul et al., 2017). Tone, in turn, is defined as the "affect" conveyed through narrative communication (Henry, 2008), reflecting linguistic choices that may influence stakeholders' perceptions. Prior research suggests that firms may strategically adjust their narrative style as an impression management mechanism, particularly when reporting more complex asset structures (Cavalheiro et al., 2021; Fisher et al., 2019).

This analysis is grounded in the findings of Ertugrul et al. (2017), who argue that reports characterized by technical language and dense structures increase the cognitive effort required for comprehension, thereby reducing their informational usefulness. Moreover, firms may deliberately employ obfuscation to conceal unfavorable information. Aldoseri and Melegy (2023) further argue

that the readability of financial reports reduces financing costs by improving informational efficiency and enhancing stock liquidity.

According to Daly and Saif (2016), the characteristics of biological assets inherently create greater uncertainty regarding future cash flows, which serve as the basis for fair value measurement. Consequently, greater (lower) uncertainty about a firm's repayment capacity leads credit providers to charge higher (lower) interest rates.

Li (2008) and Dyer et al. (2017) further demonstrate that textual characteristics, such as readability and redundancy, are sensitive to these conditions. Barth (2024) identifies several unresolved issues in international financial accounting, particularly regarding fair value measurement, which involves substantial managerial judgment, and the conservative treatment of intangible asset recognition under international accounting standards. According to the author, one of the principal concerns surrounding intangible assets is that internally generated intangibles are frequently excluded from recognition, creating inconsistencies between economic value and book value and thereby reducing the relevance of accounting information.

Within this context, it is reasonable to infer that the interaction between difficult-to-measure assets and financial leverage may amplify their effects on readability. According to Umar et al. (2022), although fair value accounting for biological assets, particularly in the agricultural sector, remains the subject of ongoing debate because of concerns regarding subjectivity and informational relevance, empirical evidence on its implications for corporate disclosure remains limited.

In a study examining the readability of risk disclosures provided by firms listed on the South African Stock Exchange, Toerien and Du Toit (2024) investigated the degree of compliance with mandatory disclosure requirements and concluded that firms operating in higher-risk sectors exhibit lower levels of readability. They also found that increased regulatory pressure failed to mitigate this problem. It is precisely this research gap that the present study seeks to address.

With respect to intangible assets, previous studies have examined their effects on the quality of accounting information and market reactions in the Brazilian context, concluding that intangible assets play an important role in this relationship. For example, Silva et al. (2017) investigated the influence of intangible assets on the value relevance of accounting information and found that their presence affects the association between earnings, shareholders' equity, and stock prices. Sousa et al. (2024) demonstrated that both the level of disclosure and the materiality of intangible assets significantly influence the value relevance of accounting information. Likewise, Moura et al. (2014) identified a substantial gap between accounting standards and corporate practice, showing that many firms fail to adequately disclose intangible assets, thereby indicating low transparency and persistent recognition challenges.

Similarly, biological assets have been examined by Souza et al. (2023) and Reid (2021), who argue that although fair value measurement seeks to more faithfully represent the economic reality of agricultural activities, it introduces substantial managerial judgment and subjectivity into the reported estimates, particularly in the absence of active markets. As a result, the comparability and reliability of financial statements may be compromised. This subjectivity may also create opportunities for earnings management practices and make it more difficult to distinguish legitimate information from intentionally biased disclosures (Souza et al., 2023).

Although this topic has received prior scholarly attention, the present study contributes to advancing knowledge regarding the factors that may affect the quality of disclosed information within

a particularly challenging context, given the measurement complexities associated with biological and intangible assets. Previous studies have not directly examined the relationship between the intensity of biological and intangible assets (i.e., complex assets) and the textual characteristics of financial statement notes, such as readability and tone, while simultaneously considering financial leverage as a moderating factor.

The study is limited to non-financial firms listed on B3 during the period from 2019 to 2023. Accounting data were obtained from the Comdinheiro database, while textual information was extracted from the notes to the financial statements. Accordingly, the findings should be interpreted within the context of this specific market and the period analyzed.

In light of the foregoing, the study seeks to answer the following research question: How does the intensity of complex assets influence the readability and tone of the notes to the financial statements disclosed by companies listed on B3? To address this question, an empirical approach was adopted to identify both the direct and moderating effects of these variables on the readability and tone of financial reports. Accordingly, the objective of this study is to examine the effects of the intensity of biological and intangible assets on the readability and tone of the notes to the financial statements of Brazilian companies listed on B3, considering the moderating effect of financial leverage.

This study contributes to the work of market analysts, investors, and other stakeholders by relating characteristics of corporate disclosure to perceptual dimensions such as readability and tone. From an academic perspective, the study also contributes by advancing robust methods for collecting and processing non-financial data, thereby enhancing research reproducibility and enabling analyses over longer time horizons.

Theoretical Foundations Of The Study

Complex Assets

The complexity attributed to biological and intangible assets is associated with the use of fair value measurement, as established in CPC Technical Pronouncement 29 – Biological Assets and Agricultural Produce and CPC Technical Pronouncement 04 – Intangible Assets (Comitê de Pronunciamentos Contábeis, 2009, 2021). The fair value approach seeks to provide a more faithful representation of the economic reality of agribusiness; however, it poses significant challenges, particularly in the absence of active markets, requiring the use of internal valuation models such as discounted cash flow analysis (Souza et al., 2023; Reid, 2021).

These valuation estimates involve a high degree of managerial judgment and technical complexity, which may negatively affect the clarity of the notes to the financial statements. Reid (2021) argues that fair value-related disclosures increase information asymmetry and reduce readability. This complexity is even more pronounced for biological assets because of their heterogeneous nature, which may vary according to species, production cycle, productivity, and associated risks, thereby requiring extensive and highly technical disclosures (Savić & Obradović, 2020). Bens et al. (2016) and Barney et al. (2017) further demonstrate that fair value reporting is associated with the excessive use of technical terminology, lengthy sentences, and, consequently,

lower readability.

Within the Brazilian context, the literature documents persistent shortcomings in the quality of disclosures related to biological assets, including a lack of standardization, insufficient disclosure of underlying assumptions, and the use of language that is difficult to understand (Camargos et al., 2021; Holtz & Almeida, 2013). These findings suggest that firms with a higher proportion of biological assets may produce less readable notes to the financial statements, creating opportunities for the use of opaque language, whether as a consequence of measurement complexity or as the result of strategic communication choices.

The literature further indicates that assets characterized by measurement complexity, such as biological assets, are associated with greater subjectivity and, consequently, with less comprehensible financial reports (Souza et al., 2023; Reid, 2021). Conversely, firms experiencing financial distress may face conflicting disclosure incentives, either increasing transparency to attract external capital or adopting more opaque language to mitigate investors' perceptions of risk (Ajina et al., 2016; Aldoseri & Melegy, 2023). In addition, intangible assets are likewise considered complex assets, as they may involve fair value measurement under specific circumstances, as well as extensive use of estimates and managerial judgment, thereby increasing the degree of subjectivity in financial reporting (Oyewo et al., 2020).

Readability and Tone of the Notes to the Financial Statements

Consistent with the concept introduced earlier, readability refers to the degree of ease with which a text can be read and understood by its readers (Flesch, 1948). It is influenced by factors such as syntactic complexity, sentence length, and the use of technical vocabulary. In financial reporting, readability is a fundamental attribute because it enables even non-specialist users to properly interpret the information disclosed (Souza et al., 2019). As an alternative measure, readability was also assessed using the Gunning Fog Index (Fog), developed by Robert Gunning in 1952. This was the first readability formula designed to estimate the number of years of formal education required for an individual to understand a text (Moreno et al., 2022). Moreover, Moreno et al. (2022) adapted both the Flesch and Fog indices to the Portuguese language and developed language-specific readability metrics, which were likewise calculated in the present study.

Previous studies have successfully applied the Flesch and Fog indices to assess the readability of financial reports (Li, 2008; Ajina et al., 2016), enabling an objective evaluation of the extent to which corporate disclosures are accessible or opaque. In particular, the Flesch Reading Ease index measures textual fluency, even in technical documents, by considering the average number of syllables per word and the average number of words per sentence, thereby producing a numerical readability score.

The higher the score, the easier the text is considered to read (Toerien & Du Toit, 2024). Beyond serving as objective readability measures, these indices have also been employed to investigate strategic managerial behavior, based on the premise that managers may deliberately reduce the readability of financial reports to soften stakeholders' perceptions of poor performance, a strategy commonly referred to as obfuscation (Bloomfield, 2008; Li, 2008).

The readability measures computed in this study enabled an assessment of textual clarity, a characteristic that has received considerable attention in empirical research because of its relationship with information asymmetry, the cost of capital, and the manipulation of users' perceptions. Ajina et

al. (2016) show that firms engaging in earnings management tend to reduce report readability in order to conceal unfavorable information. Similarly, Dyer et al. (2017) document a decline in readability over time, attributing this trend to the increasing use of generic and redundant language.

Furthermore, the literature suggests that readability may reflect either legitimate informational characteristics or managerial strategies of obfuscation (Ajina et al., 2016; Souza et al., 2019). Obfuscation has been defined by Merkl-Davies and Brennan (2008) as the deliberate use of complex language to reduce the clarity of disclosed information. Such a strategy undermines transparency and exacerbates information asymmetry between managers and investors (Merkl-Davies & Brennan, 2008; Li, 2008).

Another textual characteristic relevant to this discussion is **tone**, understood as the affective content embedded in narrative disclosures and expressed through the use of words with positive, negative, or neutral connotations (Fisher et al., 2019). This textual attribute influences how stakeholders perceive firms' risks, opportunities, and future performance, thereby functioning as a signaling mechanism (Aly et al., 2018). This dimension is consistent with disclosure theory, particularly regarding investors, who, according to Verrecchia (2001), are heterogeneous in their responses because they possess different levels and qualities of information, leading to divergent interpretations of corporate disclosures.

Tone represents an important dimension of accounting information quality because it reflects not only corporate performance but also the strategic communication choices of top management (Bassouly et al., 2020). Previous studies indicate that firms often maintain an optimistic tone in their disclosures even when reporting unfavorable financial performance, a practice commonly associated with impression management (Cavalheiro et al., 2021). Such behavior may reduce transparency and distort users' interpretation of financial information.

Within the Brazilian context, Cavalheiro et al. (2021) analyzed the tone of management reports using a word-count methodology based on a dictionary developed from the classification schemes proposed by Henry (2008) and Carlsson and Lamti (2015). The resulting tone index ranges from **-1 to +1**, with positive values indicating an optimistic tone. Their findings reveal a predominance of positive tone regardless of firms' financial performance, supporting the hypothesis of informational bias and suggesting that tone may serve as a persuasive communication tool.

Dyer et al. (2017) found that corporate narrative disclosures have become increasingly lengthy and complex over time, even though their substantive informational content has remained largely unchanged. Moreover, Fisher et al. (2019) caution that an excessively positive tone may reduce textual clarity, particularly when combined with other sources of informational complexity, such as technical language, long sentences, or difficult-to-measure assets, including biological and intangible assets. Accordingly, the following hypotheses are proposed:

H_{1a}: Firms with a higher intensity of biological assets exhibit lower readability in the notes to the financial statements.

H_{1b}: Firms with a higher intensity of intangible assets exhibit lower readability in the notes to the financial statements.

H_{2a}: Firms with a higher intensity of biological assets exhibit a more positive tone in the notes to the financial statements.

H_{2b}: Firms with a higher intensity of intangible assets exhibit a more positive tone in the notes to

the financial statements.

In testing the above hypotheses, as part of the overall objective of this study, we seek to investigate whether the intensity of biological and intangible assets is associated with the readability and tone of the notes to the financial statements. Based on the literature reviewed, the expected relationship between the intensity of biological and intangible assets and readability is negative, whereas the expected relationship with tone is positive.

Financial Leverage

The relationship between the readability of accounting information and firms' financial characteristics has been examined in both the international (Aldoseri & Melegy, 2023) and Brazilian (Souza et al., 2019) contexts. The findings indicate a negative association between readability and financial performance, suggesting that firms facing greater financial difficulties tend to disclose less readable information.

Ertugrul et al. (2017) argue that low readability and ambiguity in annual reports impose additional information-processing costs on users, which may increase the cost of external capital. This effect is particularly relevant for highly leveraged firms, as they rely more heavily on external financing.

According to Ajina et al. (2016), highly leveraged firms may adopt more complex language in their disclosures either to signal financial strength or to conceal underlying weaknesses. The authors argue that this creates ambiguity regarding the expected effect of financial leverage on readability, as leverage may either encourage greater transparency in an effort to attract investors or promote strategic opacity.

Financial leverage is measured following Souza et al. (2019) as the ratio of total liabilities (current and non-current) to total assets. This measure serves as a proxy for a firm's reliance on external financing and the level of risk perceived by creditors. In the present study, financial leverage is analyzed not only as a direct determinant of readability but also as a moderating variable in the relationship between accounting complexity and the clarity of financial disclosures.

Accordingly, higher levels of financial leverage are expected to intensify the negative effects of biological assets on readability by reinforcing the use of technical or evasive language in corporate disclosures, as reflected in the following hypotheses:

H₃: Firms with higher financial leverage exhibit lower readability in the notes to the financial statements.

H₄: Firms with higher financial leverage exhibit a more positive tone in the notes to the financial statements.

Testing these hypotheses also contributes to achieving the overall objective of the study, as financial leverage, although modeled as a moderating variable in the relationship between the intensity of complex assets and the readability and tone of the notes to the financial statements, may also represent pressure to obtain external financing and greater risk as perceived by creditors, thereby directly influencing how information is presented in the notes to the financial statements.

Accordingly, it is expected that more highly leveraged firms will resort to textual strategies that reduce the clarity of their disclosures, making them more difficult for users to interpret. Therefore, a negative relationship is expected between financial leverage and readability, and a positive relationship is expected between financial leverage and tone. These expected relationships suggest

that financial leverage serves as an incentive for rhetorical manipulation, influencing the textual characteristics of corporate disclosures in contexts of greater accounting complexity.

Complex Assets, Readability, Tone, and Financial Leverage

The literature indicates that both the technical complexity associated with the measurement of biological and intangible assets and the level of financial leverage exert independent effects on the readability of accounting information (Reid, 2021; Souza et al., 2019; Ajina et al., 2016). Toerien and Du Toit (2024) demonstrate that complex accounting standards, such as International Financial Reporting Standard 9 (IFRS 9) – Financial Instruments, which also relies extensively on fair value measurement, result in longer and less readable disclosures, reinforcing the relationship between subjective measurement and reduced informational clarity.

The central premise of this study is that firms with a high proportion of biological and intangible assets already face more demanding disclosure requirements because they must provide detailed explanations of the assumptions and estimates underlying fair value measurement. When these firms also operate with high levels of financial leverage, the incentive to adopt evasive or ambiguous language is likely to increase. In this context, as argued by Ertugrul et al. (2017), pressure to secure external financing may encourage managers to soften stakeholders' perceptions of risk, even if doing so compromises the clarity of financial disclosures.

This reasoning is consistent with the concept of informational obfuscation, according to which firms operating under adverse conditions combine complex accounting characteristics with less accessible narratives to mitigate negative market reactions (Li, 2008; Dyer et al., 2017). The simultaneous presence of factors requiring substantial managerial judgment, such as biological assets and high financial leverage, may therefore create an environment conducive to reduced textual clarity.

From this perspective, the effect of the proportion of biological assets on readability is expected to become more pronounced under conditions of higher financial leverage. In other words, financial leverage is expected to act as a negative moderator, amplifying the adverse effects of the intensity of complex assets on the quality of corporate disclosures. Furthermore, it is plausible that firms facing both high levels of complex assets and substantial debt will adopt a more positive narrative tone as a persuasive communication strategy, thereby softening perceptions of risk and reinforcing an image of financial stability.

From the perspective of the association-based Disclosure Theory (Verrecchia, 2001), firm-specific economic characteristics may be associated with observable attributes of corporate disclosure. Within this framework, the presence of complex assets and high levels of financial leverage may influence how information is communicated to external users, affecting textual attributes such as readability and tone. Based on this reasoning, the following hypotheses are proposed:

H_{5a}: The combined effect (interaction) between the intensity of biological assets and financial leverage reduces the readability of the disclosed information.

H_{5b}: The combined effect (interaction) between the intensity of intangible assets and financial leverage reduces the readability of the disclosed information.

H_{6a}: The combined effect (interaction) between the intensity of biological assets and financial

leverage results in a more positive tone in the disclosed information.

H_{6b}: The combined effect (interaction) between the intensity of intangible assets and financial leverage results in a more positive tone in the disclosed information.

These hypotheses are also aligned with the specific objectives established for this study, as they examine whether financial leverage intensifies the adverse effects of the intensity of complex assets on the readability and tone of the notes to the financial statements. In this context, firms characterized by both high financial leverage and a high intensity of biological and intangible assets are expected to adopt narrative strategies aimed at mitigating stakeholders' perceptions of risk.

Such strategies may involve the use of less readable disclosures, characterized by technical vocabulary and evasive language (an expected negative interaction effect on readability), as well as a more positive tone that serves as a tool for persuasion and impression management (an expected positive interaction effect on tone). Accordingly, financial leverage may amplify textual opacity, reinforcing the effects of accounting complexity on both the clarity of financial disclosures and the affective bias conveyed through accounting narratives.

Methodological Framework

Data and sample

The financial data required for this study were collected from the Comdinheiro database by selecting companies listed on B3 during the analysis period from 2019 to 2023. This time frame was chosen because the accounting standards applicable to biological and intangible assets had already been fully established. Furthermore, the study sought to examine a recent period while complementing prior research that investigated earlier time frames, such as 2010–2016 for biological assets (Borges & Rech, 2020) and 2015–2019 for intangible assets (Filho et al., 2024).

Following the initial collection of financial data from the study population, the sample was refined by excluding firms in the financial sector, as they are subject to industry-specific accounting regulations, as well as companies lacking the information required to operationalize the variables essential for the analyses. Table 1 summarizes the sample selection process.

Table 1 - **Sample**

Total Number of Companies for the 2019–2023 Period	452
(–) Financial sector companies	(73)
(–) Companies with missing data	(111)
= Total number of companies in the sample	268
= Total number of firm-year observations	1.436

Source: Research data

The collection of the notes to the financial statements as of **December 31** of each year during the analysis period, the processing of the retrieved files, and the computation of the dependent variables were fully automated using **six Python scripts**. According to Krotov and Tennyson (2018), automating the collection and processing of non-financial data enhances data standardization and

research reproducibility. Likewise, Keys and Zhang (2020) demonstrate that web scraping techniques are increasingly employed to extract data from the World Wide Web for accounting research.

The first script automatically accessed the Comdinheiro website (<https://www.comdinheiro.com.br/>), entered each firm's ticker symbol, located the corresponding notes to the financial statements for each ticker and fiscal year included in the sample, opened the relevant file, and downloaded it to a predefined directory. As a result, 1,588 notes to the financial statements were collected, initially in PDF format. The second script prepared the files for the computation of the dependent variables by converting the PDF documents into TXT format. Subsequently, the third script removed tables and other non-textual elements from the files. The resulting cleaned text files were then used to compute the dependent variables, as described in the following section.

Measurement of variables

Readability (Leg) is one of the dependent variables and was measured using the two metrics discussed in the theoretical framework: the Flesch Reading Ease index (Flesch, 1948) and the Gunning Fog Index. These indices were computed through the fourth Python script, using Equations 1 and 2:

$$\text{Flesch} = 206,835 - (1,015 \times \text{ASL}) - (84,6 \times \text{ASW})$$

Eq. 1

Where: ASL = average sentence length (number of words divided by the number of sentences); and ASW = average number of syllables per word (number of syllables divided by the number of words).

$$\text{Fog} = 0,4 \times [(n^0 \text{ words} / n^0 \text{ sentences}) + 100 \times (n^0 \text{ complex words} / n^0 \text{ words})]$$

Eq. 2

Based on the formulas adapted to the Portuguese language by Moreno et al. (2022), the adapted Flesch and adapted Fog indices were computed using the fifth Python script, which implemented Equations 3 and 4:

$$\text{Flesch_adapted} = 227 - 1,04 \times (n^0 \text{ of words} / n^0 \text{ of sentences}) - 72 \times (n^0 \text{ syllables} / n^0 \text{ words})$$

Eq. 3

$$\text{Fog_adapted} = 0,49 \times (n^0 \text{ words} / n^0 \text{ sentences}) + 19 \times (n^0 \text{ complex words} / n^0 \text{ words})$$

Eq. 4

The aforementioned indices were used to test Hypotheses H1a, H1b, H3, and H5 in order to assess the robustness of the findings. However, for the presentation of the results, the Flesch_adapted was adopted because it provided the best fit for the regression model, which was estimated using year

fixed effects, industry dummy variables, and firm-clustered standard errors. The remaining readability indices were retained as robustness checks.

Tone was computed using the fifth Python script, based on the dictionary of positive and negative words developed by Henry (2008), which was translated into Portuguese and applied using Equation 5:

$$\text{Tom} = \frac{(\text{Pos} - \text{Neg})}{\text{Total Words}}$$

Eq. 5

Where: Pos = number of positive words; and Neg = number of negative words.

A similar methodology was employed by Cavalheiro et al. (2021), who adapted the dictionary developed by Carlsson and Lamti (2015), which, in turn, was based on Henry (2008).

As potential predictors of readability and tone, this study includes variables representing the intensity of biological assets (Int_BA) and the intensity of intangible assets (Int_IA), as these variables capture firms' exposure to fair value measurement in the case of biological assets, together with other measurement approaches applicable to intangible assets.

The intensity of biological assets was calculated as the ratio of total biological assets to total assets, following the approach adopted by Macedo et al. (2015) and Camargos et al. (2021). Similarly, the intensity of intangible assets represents the proportion of intangible assets relative to total assets and was computed as the ratio of total intangible assets to total assets (Moura et al., 2014).

Financial leverage (Fin_Lev) serves as the moderating variable in this study and was measured as the ratio of total liabilities to total assets, following Souza et al (2019).

Variables Analyzed

The control variables, selected based on the existing literature, are firm size (Size), industry (Industry), and corporate governance (CG). Table 2 provides a summary of the variables included in the study.

Table 2 - **Research variables**

Var	Type	Measurement	Reference
Leg Flesch	Depen	$Flesch = 206,835 - (1,015 \times ASL) - (84,6 \times ASW)$ $Flesch_adapted = 227 - 1,04 \times (n^\circ \text{ words}/n^\circ \text{ de sentences}) - 72 \times (n^\circ \text{ syllables}/n^\circ \text{ words})$	Flesch (1948), Moreno et al., (2022)
Leg Fog	Depen	$Fog = 0,4 \times [(n^\circ \text{ words} / n^\circ \text{ sentences}) + 100 \times (n^\circ \text{ complex words} / n^\circ \text{ words})]$ $Fog_adapted = 0,49 \times (n^\circ \text{ words}/n^\circ \text{ sentences}) + 19 \times (n^\circ \text{ complex words} / n^\circ \text{ words})$	Moreno et al. (2022)

Tom	Depen	$\text{Tom} = \frac{\text{Pos} - \text{Neg}}{\text{Total Words}}$	Cavalheiro et al. (2021), Henry (2008)
Int_AB	Indep	Biological assets balance / Total assets	Macedo et al. (2015), Camargos et al. (2021)
Int_AI	Indep	Intangible assets balance / Total assets	Moura et al. (2014)
Alav_Fin	Indep/moder	Total liabilities / Total assets	Souza et al. (2019)
Size	Contr	Natural logarithm of total assets	Cavalheiro et al. (2021)
Sector	Contr	Industry dummy variables	Souza et al. (2023)
GC	Contr	Dummy variable for Corporate Governance segments	Souza et al. (2023)

Source: Prepared by the authors

Note: Leg_Flesch = Readability measured by the Flesch Reading Ease Index; Leg_Fog = Readability measured by the Gunning Fog Index; Int_BA = Biological asset intensity; Int_IA = Intangible asset intensity; Fin_Lev = Financial leverage; Size = Firm size; CG = Corporate governance.

The empirical models used to operationalize the variables described above are presented below.

Empirical Model

To test the proposed hypotheses, four panel data models were specified, incorporating year fixed effects and industry dummy variables, as detailed below:

Model 1 (Readability model with all variables):

$$Leg_{it} = \beta_0 + \beta_1 Int_AB_{it} + \beta_2 Int_AI_{it} + \beta_3 Alav_Fin_{it} + \beta_4 Tam_{it} + \beta_5 GC_{it} + \beta_6 LnPU_{it} \gamma_i + \delta_t + \varepsilon_{it}$$

Eq. 6

Model 2 (Tone with all variables):

$$Tom_{it} = \beta_0 + \beta_1 Int_AB_{it} + \beta_2 Int_AI_{it} + \beta_3 Alav_Fin_{it} + \beta_4 Tam_{it} + \beta_5 GC_{it} + \beta_6 LnPU_{it} \gamma_i + \delta_t + \varepsilon_{it}$$

Eq. 7

Model 3 (Readability Model with Interaction Terms Between Int_BA and Fin_Lev and Between Int_IA and Fin_Lev):

$$Leg_{it} = \beta_0 + \beta_1 Int_AB_{it} + \beta_2 Int_AI_{it} + \beta_3 Alav_Fin_{it} + \beta_4 (Int_AB \times Alav_Fin)_{it} + \beta_5 (Int_AI \times Alav_Fin)_{it} + \beta_6 Tam_{it} + \beta_7 GC_{it} + \beta_8 LnPU_{it} \gamma_i + \delta_t + \varepsilon_{it}$$

Eq. 8

Model 4 (Tone with Interaction Terms Between Int_BA and Fin_Lev and Between Int_IA and Fin_Lev):

$$Tom_{it} = \beta_0 + \beta_1 Int_AB_{it} + \beta_2 Int_AI_{it} + \beta_3 Alav_Fin + \beta_4 (Int_AB \times Alav_Fin)_{it} + \beta_5 (Int_AI \times Alav_Fin)_{it} + \beta_6 Tam_{it} + \beta_7 GC_{it} + \beta_8 LnPU_{it} \gamma_i + \delta_t + \varepsilon_{it}$$

Eq. 9

The data were organized and analyzed using an unbalanced panel dataset, which allows multiple firms to be examined over time while accommodating variation in the number of observations across firms. The models were estimated with year fixed effects and industry dummy variables to control for common temporal shocks and structural differences across economic sectors. The use of panel data enables control for unobserved heterogeneity and is well suited for longitudinal analyses based on firm-year observations (Wooldridge, 2010).

Results and discussion

Table 3 presents the descriptive statistics, providing an overview of the sample and, more specifically, of the behavior of the data with respect to their potential impact on the results of the analyses that guide this study.

Table 3 - *Descriptive statistics for the continuous variables*

Var	mean	median	sd	min	max
Leg	49.538	50.130	11.302	17.105	83.005
Tom	0.004	0.004	0.001	0.000	0.013
Int_ AB	0.000	-0.005	0.023	0.005	0.208
Int_ AI	0.006	-0.076	0.176	0.133	0.699
Alav_Fin	0.003	0.013	0.317	-0.578	1.195
Size	21.895	22.029	2.171	4.454	27.681

Source: Research data

The variables reported in Table 3 are those included in the estimated models. The data were winsorized at the 1st and 99th percentiles, resulting in stable and consistent data for analysis. Regarding readability, the mean value of 49.53 for readability (Leg) indicates that, on average, the analyzed texts present a moderate level of reading difficulty. The values for the tone variable are consistent with a measure that can assume both positive and negative values.

Firm size shows a well distributed pattern, while the variables related to the intensity of biological and intangible assets have mean values close to zero, indicating that, overall, firms' exposure to these assets is low. In summary, the behavior observed in the descriptive statistics is consistent with the correlation results presented in Table 4.

Table 4 - **Pearson Correlation**

Var	Leg	Tone	Int_AB	Int_AI	Alav_f	Size
Leg	1	-0.040	0.047	0.025	0.004	0.145
Tone	0.040	1	-0.025	0.143	-0.020	-0.374
Int_ab	0.047	-0.025	1	-0.104	-0.006	0.111
Int_ai	0.025	-0.143	-0.104	1	0.020	0.252
Alav_f	0.004	-0.020	-0.006	-0.020	1	-0.178
Size	0.145	-0.374	0.111	0.252	-0.178	1

Source: Research data

The correlation results indicate no significant multicollinearity issues among the variables of interest. Readability and tone exhibit a correlation close to zero, suggesting that they represent distinct dimensions of textual analysis. Firm size is positively correlated with readability, indicating that larger firms tend to produce more readable reports.

The intensity of biological assets exhibits only weak correlations with the other variables. In contrast, the intensity of intangible assets is positively correlated with firm size and negatively correlated with tone. Although these correlations do not imply causality, they suggest that a greater intensity of intangible assets may be associated with a less positive tone. Notably, the tone variable is negatively correlated with all variables of interest. The regression results are presented next. Table 5 reports the estimation results.

Table 5 - Regression results by estimated model

Variables	(1)	(2)	(3)	(4)
Int_AB	65.924* (25.943)	-0.001 (0.002)	-1750.145 (1593.398)	0.005 (0.143)
Int_AI	-4.538 (3.203)	-0.001* (0.000)	-44.694 (67.309)	-0.014* (0.007)
Alav_Fin	0.002*** (0.000)	-0.000*** (0.000)	-1.191 (1.036)	-0.000+ (0.000)
Size	2.223*** (0.497)	-0.000** (0.000)	2.262*** (0.508)	-0.000** (0.000)
AB × Alav_Fin			-159.216 (139.710)	0.001 (0.013)
AI × Alav_Fin			-3.564 (5.967)	-0.001* (0.001)
Num.Obs.	1435	1435	1435	1435
R2	0.029	0.213	0.029	0.217

Note: Firm-clustered robust standard errors (ticker) are reported in parentheses. Statistical significance is denoted as follows: + p < 0,10; * p < 0,05; ** p < 0,01; *** p < 0,001. Specification C: Year fixed effects and industry dummy

variables included; estimated using Ordinary Least Squares (OLS). Dependent variable: (1) and (3) = Readability; (2) and (4) = Tone. Interaction terms are included only in Models (3) and (4): Biological Assets $\times$ Financial Leverage and Intangible Assets $\times$ Financial Leverage. The reported R^2 corresponds to the conventional coefficient of determination for the estimated model, including the specified control variables and dummy variables).

The results presented in Table 5 correspond to the empirical models described in the methodology. In summary, the models include year fixed effects, industry dummy variables, and firm-clustered robust standard errors. The dependent variables are readability (measured by the Adapted Flesch Index) and tone (measured as the net proportion of positive to negative terms). The main explanatory variables are the intensity of biological assets and the intensity of intangible assets, together with the control variables financial leverage and firm size.

In Model 1, the intensity of biological assets exhibits a positive and statistically significant coefficient, suggesting that firms holding a greater proportion of biological assets produce more readable disclosures. This finding provides preliminary evidence for rejecting H1a. However, the result differs from the expected relationship based on the studies of Reid (2021) and Souza et al. (2023), who argue that biological assets are associated with greater subjectivity due to fair value measurement. One possible explanation is that firms with greater exposure to biological assets may be required to provide more detailed disclosures to justify their valuation assumptions, resulting in longer but relatively clearer narratives for users.

The effect of firm size is consistent with the correlation results reported in Table 4, showing a positive association with readability, in line with the findings of Borges and Rech (2020). The relatively low R^2 may reflect the substantial variability inherent in the readability measure.

Regarding the tone variable (Model 2), the intensity of intangible assets exhibits a negative and statistically significant coefficient. Likewise, in Model 4, the interaction between the intensity of intangible assets and financial leverage is also negative and statistically significant, indicating that, among more highly leveraged firms, the negative effect of intangible asset intensity on tone becomes even stronger. This finding provides support for Hypothesis H6b. The result contrasts with the expectation that firms would adopt a more positive tone as an impression management strategy, as discussed by Cavalheiro et al. (2021).

Instead, the findings suggest that firms with greater intensity of intangible assets employ more cautious language, possibly because of the uncertainty surrounding the recognition, measurement, and economic recoverability of these assets. Firm size exhibits a negative and statistically significant coefficient, whereas the coefficient for the intensity of biological assets is not statistically significant. The explanatory power of the tone model is moderate ($R^2 = 0.21$).

Overall, the results are consistent across the specifications with and without interaction terms and remain stable after controlling for firm characteristics and fixed effects. The principal findings are the positive and statistically significant effect of biological asset intensity on readability and the negative **effect** of intangible asset intensity on tone, which becomes more pronounced among firms with higher levels of financial leverage.

Relationship between the findings and the research hypotheses

With respect to readability, the intensity of biological assets exhibited a positive and statistically significant coefficient, indicating that firms with a higher intensity of biological assets tend to produce

more readable disclosures. Accordingly, as previously discussed, Hypothesis H1a was rejected, since the observed effect is the opposite of that predicted.

The intensity of intangible assets exhibits a negative coefficient, consistent with the expected direction; however, the coefficient is not statistically significant. Therefore, Hypothesis H1b is likewise not supported by the empirical results. Table 6 summarizes the findings for each of the research hypotheses.

Table 6 - Summary of the results for the research hypotheses

Hypotheses	Resultad	Conclusion
H1a: Firms with a higher intensity of biological assets exhibit lower readability in the notes to the financial statements.	Biological asset intensity: Positive coefficient (opposite to the expected direction) and statistically significant.	Rejected
H1b: Firms with a higher intensity of intangible assets exhibit lower readability in the notes to the financial statements.	Intangible asset intensity: Negative coefficient (as expected), but not statistically significant.	Rejected
H2a: Firms with a higher intensity of biological assets exhibit a more positive tone in the notes to the financial statements.	Biological asset intensity: Negative coefficient (opposite to the expected direction) and not statistically significant.	Rejected
H2b: Firms with a higher intensity of intangible assets exhibit a more positive tone in the notes to the financial statements.	Intangible asset intensity: Negative coefficient (opposite to the expected direction) and statistically significant.	Rejected
H3: Firms with higher financial leverage exhibit lower readability in the notes to the financial statements	Financial leverage: Positive coefficient (opposite to the expected direction) and statistically significant	Rejected
H4: Firms with higher financial leverage exhibit a more positive tone in the notes to the financial statements.	Financial leverage: Negative coefficient (opposite to the expected direction) and statistically significant.	Rejected
H5a: The combined effect (interaction) between the intensity of biological assets and financial leverage reduces the readability of the disclosed information.	Interaction between biological asset intensity and financial leverage: Negative coefficient (as expected), but not statistically significant.	Rejected
H5b: The combined effect (interaction) between the intensity of intangible assets and financial leverage reduces the readability of the disclosed information.	Interaction between intangible asset intensity and financial leverage: Negative coefficient (as expected), but not statistically significant.	Rejected
H6a: The combined effect (interaction) between the intensity of biological assets and financial leverage results in a more positive tone in the disclosed information.	Interaction between biological asset intensity and financial leverage: Positive coefficient (as expected), but not statistically significant.	Rejected

H^{6b}: The combined effect (interaction) between the intensity of intangible assets and financial leverage results in a more positive tone in the disclosed information	Interaction between intangible asset intensity and financial leverage: Negative coefficient (opposite to the expected direction) and statistically significant	Supported
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Source: Research data

As shown in Table 6, financial leverage exhibited a positive and statistically significant coefficient in the regressions where readability was used as the dependent variable. This finding contradicts the theoretical expectation that more highly leveraged firms would disclose less readable information, leading to the rejection of Hypothesis H₃. One possible interpretation is that firms with greater reliance on external financing seek to produce clearer disclosures as a means of reducing information asymmetry and enhancing their credibility with creditors and investors. When the interaction effects between biological asset intensity and financial leverage (H_{5a}) and between intangible asset intensity and financial leverage (H_{5b}) were examined, both interaction terms were statistically insignificant. Therefore, no evidence was found that financial leverage intensifies the effects of complex asset intensity on readability, leading to the rejection of H_{5a} and H_{5b}.

Regarding tone, the intensity of biological assets exhibited a negative coefficient, although it was not statistically significant. Accordingly, no evidence was found that firms with a greater intensity of biological assets adopt a more positive tone in the notes to the financial statements, as predicted by Hypothesis H_{2a}, which was therefore rejected. Likewise, contrary to expectations, the intensity of intangible assets exhibited a negative and statistically significant coefficient, suggesting that greater intangible asset intensity is associated with the use of less positive language in the notes to the financial statements. Consequently, Hypothesis H_{2b} was rejected. Financial leverage also exhibited a negative and statistically significant coefficient, contrary to the expectation that more highly leveraged firms would adopt more optimistic language as an impression management strategy.

The regressions incorporating the moderating effect of financial leverage on the intensity of biological assets led to the rejection of Hypothesis H_{6a}, since the interaction between these variables was not statistically significant in the model where tone was the dependent variable. In contrast, the negative and statistically significant coefficient of the interaction between intangible asset intensity and financial leverage supported Hypothesis H_{6b}, indicating that, among more highly leveraged firms, the effect of intangible asset intensity on tone becomes even more negative. This finding suggests that financial leverage acts as a factor that strengthens the association between intangible assets and a more cautious narrative in the notes to the financial statements.

Final Considerations

This study aimed to analyze the effects of the intensity of complex assets, specifically biological and intangible assets, on the readability and tone of the notes to the financial statements of Brazilian companies listed on B3, while considering the moderating effect of financial leverage.

The results indicate that the expected effects of the intensity of biological and intangible assets on the readability and tone of the notes to the financial statements were not confirmed, suggesting that these assets do not constitute factors that negatively influence readability. These findings also suggest that the aspects examined in this study do not corroborate previous research that assessed the

degree of compliance of corporate disclosures with applicable accounting standards.

Macedo et al. (2015) evaluated the compliance of the notes to the financial statements of publicly traded Brazilian companies with the disclosure requirements established by CPC 29 and found that the level of compliance was low and heterogeneous across firms, with many mandatory disclosures omitted. Similarly, Camargos et al. (2021) investigated whether the notes to the financial statements of agribusiness companies listed on B3 complied with the requirements of CPC 29 and also reported a low level of compliance, concluding that fair value measurement may be associated with a lack of standardization in corporate disclosures.

By combining financial and non-financial data, the present study found that firm size is positively associated with greater readability of financial reports, a result consistent with Macedo et al. (2015), who likewise identified a positive relationship between firm size and disclosure quality. Another important finding concerns the interaction between intangible asset intensity and financial leverage, suggesting that, among more highly leveraged firms, the effect of intangible asset intensity on tone becomes even more negative.

Regarding the findings that diverged from the theoretical expectations, it is worth revisiting the conclusions of Ajina et al. (2016), who argue that highly leveraged firms may adopt more complex language in their disclosures either to signal financial strength or to conceal underlying weaknesses. According to these authors, this creates ambiguity regarding the expected effect of financial leverage on readability, as leverage may encourage either greater transparency in an effort to attract investors or greater strategic opacity.

From the perspective of Disclosure Theory (Verrecchia, 2001), the findings suggest that the presence of complex assets is not necessarily associated with lower readability, indicating that the economic complexity of these assets does not automatically translate into lower textual quality in corporate disclosures.

One limitation of this study is the 2019–2023 analysis period, which may have been affected by the COVID-19 pandemic, a period during which changes in firms' operating environments and working arrangements may have influenced disclosure practices independently of the asset characteristics examined. Another limitation concerns the measurement of the study variables, particularly the dependent variables, which remain in need of further methodological refinement and empirical validation. In addition, the relatively small number of firms holding biological assets posed a challenge for the empirical analysis.

Future research should further investigate the relationship between the financial and non-financial information associated with biological and intangible assets in order to better understand how, and to what extent, these assets affect the quality of corporate disclosures and, consequently, the information available to stakeholders.

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