The Narrative Disclosure of R&D Activities and the Investment Efficiency of Semiconductor Firms

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Abstract

This research uses 116 semiconductor companies in Taiwan and explores the readability of narrative disclosures of R&D activities and its effect on corporate investment efficiency. These 116 Taiwanese firms together account for the second-largest market share of the global semi-conductor industry. The study finds that readability of R&D narrative disclosures in annual announcements had a positive and significant effect on corporate investment efficiency. Specifically, the content and readability of these narrative disclosures alleviates information asymmetry. When the information gap diminishes, investors are more likely to lower their demand for risk premiums and the cost of equity. Companies may then enjoy stronger leverage for external financing, thus increasing their investment efficiency. The evaluation of narrative disclosures is based on a three-year period, rather than one year. A difference matrix to measure investment efficiency is applied in the sensitivity analysis and demonstrates similar results.

Keywords: Narrative Disclosure of R&D Activities, Readability, Investment Efficiency.

1. Introduction

Capital investment and R&D activities affect a firm's economic and resource distribution and figure importantly in corporate growth, value, and performance. These investments usually require a significant amount of internal and external financial resources such as internal capital, external loans, or stock issuance. Investment, however, can be inefficient, as in over- or under- investment. Researchers have proposed the pecking order theory and the free cashflow hypothesis to explain information asymmetry between managers and external stakeholders and the resulting investment inefficiency (Myers and Majluf, 1984; Jensen, 1986; Almeida and Campello, 2007; Lu and Wang, 2015). Efficiency is sometimes defined by investment in projects with positive net present value (NPV) or aversion to those with negative NPV. Biddle et al. (2009) evaluate investment efficiency by the degree of deviation of actual investment from expected investment: a positive deviation indicated over-investment and negative, under-investment. Sometimes corporate managers over-invest for self-interested or undertake projects with negative NPV for speculation (Jensen and Meckling, 1976). To improve investment efficiency, previous research identified the quality of financial reports and external supervision as the key. For example, Ball and Shivakumar (2005), and Biddle et al. (2009) demonstrated that a quality financial report mitigated information asymmetry, increased investment efficiency, and lowered the cost of capital. Lambert, Leuz, and Verrecchia (2007) confirm that better earnings quality was positively related to investor's supervising power, which prevented managers from making investments detrimental to corporate value. Research has also found that companies with higher accounting conservatism enjoyed more robust future profitability, suggesting a positive correlation between accounting conservatism and investment efficiency (Watts, 2003; Ball and Shivakumar, 2005; Francis and Martin, 2010; Ahmed and Duellman, 2011; Lu and Wang, 2015; and Lara et al. 2016). Lu and

Wang (2015) find that board independence was negatively related to capital investment but was positively related to R&D investment. This meant that a board with a higher level of independence was more effective in supervising a firm's investment decisions.

The semiconductor industry in Taiwan provides a useful example. IC designers (downstream clients) begin the process of discussing and reserving capacity for the coming year with their IC OEM manufacturers (upstream suppliers) at the end of the third quarter or in the fourth quarter each year. Semi-conductor heavyweight TSMC (TWSE: 2330, NYSE: TSM) has maintained the same R&D intensity since its establishment thirty years ago, investing 8% of revenue into R&D, an incredible number that supports the company's impressive R&D capability. In the 2Q2023 investors conference, TSMC announced over 5.5 billion USD of R&D investment and 32-36 billion USD of capital expenditure in 2023 for clients' future applications in AI, HPC, and 5G. Generally speaking, upstream suppliers make relationship-specific investments for client orders and product manufacturing. In order to evaluate the financial results of such investment and achieve better efficiency, suppliers assess the accounting performance, earnings outlook, and other non-financial information of their downstream clients before making any investment decisions. Research shows that supply chain partners (upstream suppliers and downstream clients), just as external financial providers such as shareholders and creditors, pay close attention to accounting information when making deals. Hui et al. (2012) find that business partners took accounting performance into consideration when evaluating their counterparts' ability to fulfill contracts.

Research indicates that the information in financial reports serves to reduce information asymmetry and the cost of capital (Blanco et al., 2015). Merkley (2014) further suggests that narrative disclosures bridge the gap between the accounting numbers in financial statements and the underlying fundamentals of a company. These

disclosures, especially of R&D activities, alleviate information asymmetry because they contain more internal information and provide a clear picture of a company's innovation outlook. Guo et al. (2004) find that information asymmetry between firms and outsiders falls when more information on R&D activities is made available. Non-financial information in annual reports has also been shown to affect the investment decisions of supply chain partners. For example, Chen et al. (2019) analyze the quality of management earnings forecast reports (MEFRs) and its effect on the investment decisions of upstream suppliers and confirmed a positive correlation between the two. In their investigation of the relationship between downstream clients' disclosures of risk factors in annual reports and their upstream suppliers' investment efficiency, Chiu et al. (2019) indicate that more information on risk factors (better readability) provided by downstream clients could reduce abnormal investments (under- or over-investments) and increase investment efficiency for upstream suppliers. These studies have provided many insightful results. However, to the best of our knowledge, very few studies have analyzed the R&D narrative disclosure of a company and how it affects its own investment efficiency, along with the investment efficiency of upstream suppliers.

The semiconductor industry in Taiwan began taking off in the 1980s, with UMC (TWSE: 2303, NYSE: UMC) as its first listed company. Over the past forty years, the industry has evolved to include over 1,000 players and built one of the most advanced and cost-efficient production models in the world, an eco-system almost un-reproducible and unreplaceable by other countries. The production value of the semiconductor market in Taiwan has grown by more than three times the global average since 2000, securing Taiwan in a key position in the global supply chain. Unlike integrated device manufacturers (IDM) such as Intel and Samsung, Taiwanese semiconductor companies focus on the individual value chain of IC design, wafer fab, and packaging and testing, and operate by a model of vertical specialization. World-

renowned semiconductor foundry TSMC (TWSE: 2330, NYSE: TSM) has the most advanced processing technology and produces 5G, AI, and HPC chips for US leading companies such as Apple, AMD, and Nvidia. Its global market share rose from 53.1% in 2021 to 55.5% in 2022 and is likely to continue this upward trend in 2023 thanks to the steady increase of 3/4/5nm input from major US clients (IDC 2023). Furthermore, Goldman Sachs indicated that Intel may increase outsourcing to TSMC, making TSMC's overall market potential for outsourcing orders in 2024 and 2025 to be an estimation of $18.6 billion and $19.4 billion.

The semiconductor industry is highly R&D intensive. Stakeholders in this sector rely on the R&D information revealed in annual reports before making any investment decisions. To investigate the effect of this narrative information, this research uses 116 semiconductor companies in Taiwan during 2010 to 2020 and examines the quality of R&D narrative information disclosed by companies and its effect on the abnormal investment and investment efficiencies of companies. Abnormal investment (under- and over-investment) and investment efficiency are two sides of the same coin: a larger investment anomaly means lower investment efficiency. In this paper, the quality of narrative disclosure is assessed based on the readability of R&D contents. Specifically, we examine whether better readability of R&D narrative disclosures by companies results in smaller investment anomalies and higher investment efficiency for the companies.

The study finds that better readability of narrative disclosures of R&D activities in annual reports increases a firm's investment efficiency. The content and readability of narrative disclosures ameliorate information asymmetry, lowering investor demand for risk premiums and cost of equity. With reduced cost of capital, a firm has more room to acquire external finance to address investment hold-up problems and to increase investment efficiency.

This paper emphasizes the narrative disclosures of R&D activities taking into account the following factors. First, continuous innovation is a major source of competitive advantage. Research confirms the positive and deferred benefits of R&D investment on corporate value and performance. Companies in general also regard R&D investment as a key driver of growth and competitiveness (Lev and Sougiannis, 1996). Second, R&D involves a high degree of uncertainty and risks (Ahmed and Falk, 2009). Therefore, R&D investment is mandated by accounting principles to be expensed in financial reports unless it meets the conditions of a certain development phase and can be capitalized. This means that the R&D expenditure has a negative impact on the current accounting earnings. As earnings results are a key index of management performance, managers are motivated to speculatively reduce R&D expenditure and increase reported earnings in order to achieve stronger performance, win higher bonuses, and secure their jobs. This may result in agency problems. Third, Wolfe (2022) indicated that the overall R&D expenditure of 538 billion U.S dollars for US companies in 2020 registered an increase of 9.1% from 2019. This gigantic amount of R&D investment had to be disclosed as figures in financial reports and be projected into future results for investors, which then highlighted the value of narrative disclosure (Wolfe, 2010). A crucial dimension of R&D narrative disclosure is its content. Products and services under development, technology and R&D conditions, short- to long-term business plans, competitive edges, positives and negatives in the outlook, and potential strategies, in sum, all the data concerning the progress of R&D activities or the forward-looking information of market demand and future development, represent important information for disclosure. R&D activities require a significant amount of financial support. As managers and shareholders may have different decisions period and risk attitude (Christopher and Rahul, 2012), they may come into conflicts with regards to R&D investment benefits. This could lead to information asymmetry and affect a firm's

cost of equity and its external financing access. Inefficient investment appearing as under- or over-investment may then occur.

The remainder of the paper is organized as follows. Section 2 surveys the literature and presents the research hypotheses. Section 3 lays out the research design. Section 4 is contributed to the empirical results. The sensitivity analyses are provided in Section 5. Section 6 concludes this research.

2. Literature Review and Research Hypothesis

Investment activities are crucial to corporate growth. Efficient investment decisions help generate more cash flow and profits for companies. However, inefficient investment sometimes occurs because of adverse selection and moral hazard, and because of the information asymmetry among investors and managers. This increases the cost of capital for external financing, forcing companies to forego investment projects with lower net realizable value. Baker, Stein, and Wurgler (2003) find that corporate managers, having more internal information than investors, choose the timing of capital increase and issue shares at higher offering prices for over-investment. Richardson (2006) showed that companies with strong cash flow were more likely to execute investment projects detrimental to shareholder wealth maximization, indicating positive links between free cash flow and over-investment. By contrast, Lambert et al. (2007) found that creditors exercised their power of loan granting to prevent moral hazard and force companies to drop investment projects with positive net present value due to insufficient capital.

To bridge information gap, lower cost of capital, and improve investment efficiency, a quality financial report is important (Ball and Shivakumar, 2005; Biddle et al., 2009). Biddle and Hilary (2006) and Chen et al. (2011) indicated that accounting

information affected corporate investment decisions by serving the purposes of: (1) mitigating the imperfection inherent in stock markets; (2) enhancing investment decision accuracy; and (3) assisting external financial providers in supervising corporate operations. Better earnings quality helps strengthen investors' supervision power, preventing managers from implementing investment projects that jeopardize corporate value (Lambert et al., 2007). In addition, accounting conservatism has been shown to be positively related to corporate future profitability as well as investment efficiency (e.g., Watts, 2003; Ball and Shivakumar, 2005; Francis and Martin, 2010; Ahmed and Duellman, 2011; Lara et al. 2016).

Diamond and Verrecchia (1991), and Blanco et al. (2015) also suggest the information in annual reports and its importance in lowering information asymmetry and cost of capital. Francis et al. (2005) confirm that new information and how they were interpreted by investors will eventually be reflected in the risk premium and cost of equity. Investors are more likely to reduce the risk premium if they consider the news effective in narrowing the information gap and sending a positive message about the operational and profit outlook. Conversely, if investors regard the information as negative, they will project riskier future operations and demand a higher risk premium.

It is important to note that operational information includes not only accounting numbers but also a description of historical events or forward-looking statements. For example, a company's letter to shareholders usually describes the financial and operational conditions, challenges and risks, and future outlook. Along with the information itself, the wording, tone, and readability in these letters are important clues for external stakeholders when making investment decisions. Unlike accounting information that requires independent auditing, these narrative disclosures permit managerial discretion to organize the text. Companies will attempt to project a more optimistic tone in their earnings press release (EPR) if they expect future accounting

performance to decline, their accounting report to be restated, or strategic activities such as capital increase or M&A to be initiated (Huang, Teoh, and Zhang 2014). The more positive an EPR, the stronger the stock price's upward trend (Davis, Piger, and Sedor, 2012). In addition to the tone, companies sometimes manipulate the readability to exert influence on outsiders' decisions. Information presented with poor readability is less practical and applicable. Li (2008), Asay, Libby, and Rennelamp (2018), and Kim, Wang, and Zhang (2019) find that companies tended to make annual reports or narrative disclosures less readable when earnings were lower. Annual reports with many esoteric terms also indicated weaker future earnings persistence. Merkley (2014) suggest that when investor demand for corporate information was strong, the frequency of R&D related words was negatively related to the current earnings performance. Other studies revealed that the frequency of description of investment activities was positively linked to stock prices and corporate value (i.e., Nekhili, Boubaker, and Lakhal, 2012). Hsieh et al. (2016) indicate that readability of analyst reports was especially important to stock price reaction when information asymmetry worsened (higher R&D investment, more concentration of shareholdings on individual investors, larger spread between selling and buying prices): when analyst reports were more reader-friendly, investors were more likely to react positively to the recommended company. In wake of these findings, it is understandable that the United States Securities and Exchange Commission (SEC) have suggested improving report readability by using short sentences and avoiding technical jargon when presenting operational information or risk events to external stakeholders (Chang, Chi, and Stone., 2022).

The results of R&D investment are usually less predictable (Ahmed and Falk, 2009) and its costs are considered expenses unless certain conditions for capitalization are met. Therefore, R&D expenditure can have a negative impact on accounting earnings. In addition, R&D results are registered as intangible assets and cannot be used

as collateral for financing. Such non-collaterability means that companies with stronger demand for R&D investment have less economic flexibility and face more financing obstacles (Brown and Bruce, 2011). Furthermore, the uncertain benefits of huge R&D investment on corporate profitability could exacerbate the information asymmetry between companies and investors. Guo et al. (2004) indicated that more information on R&D investment lessened information asymmetry between companies and external stakeholders.

Information on the quantity and intensity of R&D activities is usually disclosed in financial reports, but sometimes the message on their underlying value is lost in the numbers (Franzen et al., 2007). For investors, it is important to obtain better ideas of R&D results and their impact on future profitability before making any investment decisions. Indeed, R&D investment highlights the importance of narrative disclosures of non-financial data (Wolfe, 2010). Merkley (2014) suggests that narrative disclosures could bridge the gap between accounting numbers and operation fundamentals and that its quality was the key to mitigating information asymmetry. More information on products and services to be developed, the R&D condition of new technologies and products, analyses of product competitiveness, and information concerning R&D and operation outlook can be revealed in narrative disclosures and can reduce information asymmetry.

This study infers that the content and readability of R&D narrative disclosures in annual reports affects the investors' interpretation of financial information, their evaluation of corporate risk and risk premium, and their requirement for the cost of equity. A lower cost of equity allows companies more flexibility in seeking external finance to solve the problem of under-investment or to increase value-added projects. Therefore, we infer that the quality of the non-financial report (measured by the

readability of R&D narrative disclosures) could increase investment efficiency. We thus construct Hypothesis 1:

Hypothesis 1: Better readability of R&D disclosures in annual reports increases corporate investment efficiency.

3. Research Design

3.1 Data Source and Research Period

This research investigates 116 listed semiconductor companies in Taiwan during the period 2010 to 2020, focusing on the effect of R&D narrative disclosures on the investment efficiency of companies themselves as well as supply chain peers. Information on R&D narrative disclosures is collected from corporate annual reports. The accounting and financial data of sample firms are obtained from the database of Taiwan Economic Journal (TEJ).

The sampling criteria are as follows: (1) firms not using a December fiscal year-end for all sample periods are deleted; and (2) firms with incomplete accounting and financial data, and those listed as full cash delivery stocks or whose trading in stocks was terminated by the Taiwan Stock Exchange, are excluded. These criteria result in a 116 companies with 1,128 samples for Hypothesis 1 and 2,648 samples for Hypothesis 2. This research adopts a 5% and 95% winsorization for all continuous variables to eliminate the effect of spurious outliers.

In contrast to integrated device manufacturers (IDM) such as Intel and Samsung, most Taiwanese semiconductor companies focus on a single supply chain of IC design, foundry, packaging and testing, and execute vertical specialization. Among these 116 firms, 60 (52%) are IC designers, 24 (20%) are wafer manufacturers, and 32 belongs to the packaging and testing sector (28%).

3.2 Empirical Models

3.2.1 Readability of R&D Narrative Disclosures and its Effect on Corporate Investment Efficiency

This research refers to Biddle and Hilary (2006), Richardson (2006), Biddle et al. (2009), Chen et al. (2011), Rad et al. (2016), and Chiu et al. (2019) and establishes empirical model as follows.

$$\begin{aligned} INVEFF_{i,t}^{new} &= \alpha_0 + \beta_1 READ_{i,t-1} + \beta_2 SIZE_{i,t} + \beta_3 RDI_{i,t} + \beta_4 COD_{i,t} + \\ &\beta_5 COE_{i,t} + \beta_6 P/B_{i,t} + \beta_7 SlACK_{i,t} + \beta_8 TANG_{i,t} + \beta_9 CFO_{i,t} + \\ &\beta_{10} K\_Structure_{i,t} + \beta_{11} OPCYCLE_{i,t} + \beta_{12} BLOCK_{i,t} + \\ &\beta_{13} INST_{i,t} + \beta_{14} ROA_{i,t} + \beta_{15} LOSS_{i,t} + YEAR_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (1)$$

$INVEFF_{i,t}^{new}$: investment efficiency of firm *i* in year *t*

$READ_{i,t-1}$: readability of R&D disclosures by firm *i* in year *t*-1

$SIZE_{i,t}$: corporate size of firm *i* in year *t*. The natural logarithm of year-end total assets is taken to represent proxy variables.

$RDI_{i,t}$: research intensity of firm *i* in year *t*, measured by the ratio of R&D expenses to net revenue.

$COD_{i,t}$: cost of debts for firm *i* in year *t*. This research follows Francis et al. (2005) and divides interest expenses by the average of interest-bearing debts. The averaged interest-bearing debts is the combination of beginning and year-end short-term loans, commercial paper payables, accounts payables, notes payables, and long-term debts divided by 2.

$COE_{i,t}$: cost of equity capital of firm *i* in year *t.* This research adopts the CAPM (capital asset pricing model) of Sharpe (1964) and measures the cost of equity capital as such:

$$E(R_{i,t}) = R_{f_t} + \beta_{i.t}(R_{m_{i,t}} - R_{f_t})$$

where$E(R_{i,t})$ denotes the ratio of cost of equity, and R_{f_t} as risk-free interest. We apply the one-year time deposit

interest rates of Taiwanese banks each year as the estimate for risk-free return rate. $R_{m_{i,t}} - R_{f_t}$ represents ex-right and ex-dividend adjusted annual return rate of Taiex for the previous 10 years in year *t* minus risk-free interest rate in year *t*. $\beta_{i.t}$ stands for the five-year Beta coefficient.

$P/B_{i,t}$: price-to-book ratio of firm *i* in year *t*.

$SLACK_{i,t}$: financial slack of firm *i* in year *t*. It is measured by year-end cash and cash equivalents plus short-term investment and then deflated by year-end total assets.

$TANG_{i,t}$: tangible assets intensity of firm *i* in year *t*, represented by the total of year-end property, plant, and equipment divided by year-end total assets.

$CFO_{i,t}$: operating cash flow ratio of firm *i* in year *t*, calculated by current year operating cash flow divided by year-end total assets.

$K\_Structure_{i,t}$: capital structure of firm *i* in year *t*. This research uses the method of Biddle and Hilary (2006) and adopts the non-current assets/(non-current debts + market capitalization) as the proxy variable of capital structure.

$OPCYCLE_{i,t}$: natural logarithm of operating cycles for firm *i* in year *t*.

$BLOCK_{i,t}$: holding ratio of major stakeholders for firm *i* in year *t*.

$INST_{i,t}$: holding ratio of institutional investors for firm *i* in year *t*.

$ROA_{i,t}$: total return on assets for firm *i* in year *t*.

$LOSS_{i,t}$: dummy variable of net loss after tax for firm *i* in year *t*.

$YEAR_{i,t}$: dummy variable of controlled year-fixed effect.

$\varepsilon_{i,t}$: residual terms.

Hypothesis 1 in this study expects the coefficient β_1 of $READ_{i,t-1}$ to be positive. This means that better readability of R&D narrative disclosures in annual reports is positively related to the corporate investment efficiency after such disclosures.

3.3 Variable Measurements

Investment efficiency ($INVEFF_{i,t}^{new}$; $INVEFF_{up,t}^{new}$)

Following Richardson (2006), this research adopts the following equation to measure a firm's expected investments and investment efficiency.

$$\begin{aligned} INV_{i,t}^{new} = {} & \alpha_0 + \beta_1 INV_{i,t-1}^{new} + \beta_2 SIZE_{i.t-1} + \beta_3 LEV_{i,t-1} + \beta_4 CASH_{i,t-1} + \\ & \beta_5 AGE_{i,t-1} + \beta_6 TOQ_{i,t-1} + \beta_7 RETURN_{i,t-1} + \\ & \sum_{2011}^{2020} \Delta_{1k} YEAR_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (2)$$

where $INV_{i,t}^{new}$ indicates expenditure on new investment projects of firm *i* in year *t*, deflated by beginning total assets. $SIZE_{i.t-1}$ is the natural logarithm of total assets of firm *i* in *t*-1 year. $LEV_{i,t-1}$ represents the debt/equity ratio of firm *i* in *t*-1 year. $CASH_{i,t-1}$ denotes cash plus short-term investments of firm *i* in *t*-1 year, deflated by year-end total assets. $AGE_{i,t-1}$ is years of establishment of firm *i* in *t*-1 year. $TOQ_{i,t-1}$ is Tobin's Q of firm *i* in *t*-1 year. $RETURN_{i,t-1}$ stands for stock return of firm *i* in *t*-1 year. $YEAR_{i,t}$ is the dummy variable of year. $\varepsilon_{i,t}$ represents the error term.

As previously demonstrated, Equation (2) calculates the annual expected investment of firms ($\overline{\mathrm{INV}}_{i,t}^{\mathrm{new}}$). We then subtract expected investment from actual investment ($\mathrm{INV}_{i,t}^{\mathrm{new}}$) to obtain $\mathrm{XINV}_{i,t}^{\mathrm{new}}$, whose residual represents the amount of inefficient investment amount. A positive residual indicates over-investment and a negative, under-investment. $\mathrm{XINV}_{i,t}^{\mathrm{new}} = \mathrm{INV}_{i,t}^{\mathrm{new}} - \overline{\mathrm{INV}}_{i,t}^{\mathrm{new}}$, where $\mathrm{XINV}_{i,t}^{\mathrm{new}}$ denotes the abnormal investments of firm *i* in year *t*.

To better illustrate the relation between R&D narrative disclosures and investment efficiency, this research follows Rad et al. (2016) and multiplies the absolute value of $\mathrm{XINV}_{i,t}^{\mathrm{new}} = \mathrm{INV}_{i,t}^{\mathrm{new}} - \overline{\mathrm{INV}}_{i,t}^{\mathrm{new}}$ where (-1) is the proxy variable of investment efficiency

$INVEFF_{i,t}^{new} = -1 * |INV_{i,t}^{new} - \overline{INV_{i,t}^{new}}|$. A larger value of $INVEFF_{i,t}^{new}$ means better investment efficiency for that year.

Readability of R&D Narrative Disclosures ($READ_{i,t-1}$; $READ_{down,t-1}$)

We follow Merkley (2014) and establish a pool of keywords for the R&D vocabulary: application, research (project, collaboration, center, facility), R&D, development, specification, design, technologies, technology breakthrough, product engineering, production processes, yield, capacity, put into production, certified, techniques, process amelioration, and patents. Paragraphs in the annual reports where these terms appeared are collected to represent the narrative disclosures of current R&D activities of the firm. For readability of R&D narrative disclosures of firm *i* in fiscal year *t*, this research uses number of characters and the Gunning Fog index as a proxy variable.

Readability 1 ($READ1_{it}$)

Li (2008), Loughran and McDonald (2014) and Ertugrul et al. (2017) indicated that more characters/words in a text lead to lower readability. This research uses the number of Chinese characters in the current R&D narrative disclosure of a firm to proxy readability. To better demonstrate the empirical results, this research defines Readability 1 as the natural logarithm of the number of characters in R&D text multiplied by (-1). A higher value means better readability of the R&D text.

Readability 2 ($READ2_{it}$)

The Chinese Readability Index Explorer developed by Song et al. (2013) is applied in this paper to calculate the fog index of the R&D narrative disclosures. A higher index means lower readability. This research defines Readablity 2 as the Fog index of Chinese

text multiplied by (-1). A higher value represents better readability of the key investigated items. The readability formula of Song et al. (2016) and Chang et al. (2022) is shown below.

Fog index of text = 4.53 + (0.01 × Number of difficult terms) – (0.86× Ratio of simple sentences) – (1.45× Logarithm of the average content-word frequency) + (0.02 × number of personal pronouns).

The number of difficult terms indicates the total number of terms/words not included in the list of common words. The ratio of single sentences stands for the proportion of simple sentences in the text. The average of content word logarithm denotes the averaged logarithm of number of content words in the text. The number of personal pronouns is the totality of personal pronouns in a text.

Content words means words contain specific lexical meanings and represent concrete things, objects, action, or condition. They include nouns, verbs, adjectives, etc. Song et al. (2015) explained that a sentence with more content words required more time to understand. A text with more content words is meant to express more concepts and hence is less easy to understand.

4. Empirical Results

4.1 Descriptive Statistics

Table 1 presents the descriptive statistics. All the continuous variables have been Winsorized by 5% to prevent the impact of extreme values. In Panel A of Table 1, the average and medium of investment efficiency of sample firms in Hypothesis 1 $INVEFF_{i,t}^{new}$ stand at -4.774 and -3.509, respectively. The level of investment anomaly has been multiplied by (-1). Therefore, higher values (closer to 0) indicate higher

investment efficiency. Readability 1 ($READ1_{i,t-1}$) calculates the wordcount of corporate R&D narrative disclosures and multiplies the natural logarithm of wordcount by (-1). The average and medium of this variable are -8.186 and -8.244. Readability 2 ($READ2_{i,t-1}$) indicates the Fog Index of R&D narrative disclosures multiplied by (-1). The average is -2.252 while the median is -2.242. The average and median of corporate size ($SIZE_{i,t}$) are 15.373 and 15.164. R&D intensity ($RDI_{i,t}$) shows an average of 13.472% and a median of 8.335%. The average and median of cost of debt ($COD_{i,t}$) are 1.314% and 0.851% while those of cost of equity ($COE_{i,t}$) are 7.690% and 7.687%. The price-to-book value ($P/B_{i,t}$) has an average of 2 and a median of 1.515, indicating sizable growth potential for sample firms on average. The average and median of institutional shareholding ($INST_{i,t}$) stand at 39.521% and 34.684%, implying that semiconductor companies in general have a higher percentage of institutional or foreign investors. The return on assets ($ROA_{i,t}$) has an average of 3.511% and a median of 5.090%. The average of operational loss for firms in year *t* is 0.285, indicating a net loss after tax for 28.5% of the total sample firms.

Panel B of Table 1 demonstrates that the investment efficiency of upstream suppliers ($INVEFF_{up,t}^{new}$) in Hypothesis 2 has an average value of -4.951 and medium of -3.913. The average and medium of Readability 1 for downstream companies ($READ1_{down,t-1}$) are -8.324 and -8.385. Readability 2 of these companies ($READ2_{down,t-1}$) is represented by the Fog index of R&D narrative disclosures multiplied by (-1) and has an average of -2.363 and a median of -2.333.

Insert Table 1

4.2 Correlation Coefficients

This research also examines the multicollinearity among independent variables by using the variance inflation factor (VIF).

4.2 Empirical results

4.3.1 Effect of R&D Narrative Disclosures on Corporate Investment Efficiency

Table 2 demonstrates the effect of R&D narrative disclosures on corporate investment efficiency. Model 1 in this table shows that for wordcount as a proxy variable of readability, $READ1_{i,t-1}$ is positively significant related to $INVEFF_{i,t}^{new}$ (regression coefficient: 0.392, *t* value: 1.98; significance level: 5%), with Adj. R^2=9.81%. In Model 2 where the fog index is used as the proxy variable for readability, $READ2_{i,t-1}$ also exhibits a significantly positive relationship with $INVEFF_{i,t}^{new}$ (regression coefficient: 0.556, *t* value: 1.93; significance level: 10%), with Adj. R^2=9.79%. These findings support Hypothesis 1, which suggests that better readability of R&D narrative disclosures in corporate annual reports enhances the corporate investment efficiency in the following year. Since none of the VIF values of these independent variables exceeds 10, no multicollinearity problem exists in our regression models.

For the controlled variables, $SIZE_{i,t}$ is positively and significantly related with $INVEFF_{i,t}^{new}$, implying that firms of larger size have higher investment efficiency. The relationship between $TANG_{i,t}$ and $INVEFF_{i,t}^{new}$ is significantly negative. This indicates that higher tangible assets intensity has a negative impact on corporate investment efficiency. Finally, $CFO_{i,t}$ is significantly and positively related to $INVEFF_{i,t}^{new}$, suggesting higher operating cashflow helps boost corporate investment efficiency.

Insert Table 2

5. Sensitivity Analysis

5.1 Will different measurements for the readability of R&D narrative disclosures affect the research results?

To make our results more robust, this study conducts a sensitivity analysis and applies the average of readability of R&D narrative disclosures in the annual reports for the previous three years.

Table 3 shows that the average readability of R&D narrative disclosures from year *t*-1 to year *t*-3 is significantly and positively related with the investment efficiency in fiscal year *t*. The coefficients of $READ1_{i,avg}$ and $READ2_{i,avg}$ are 0.5 and 0.665, both reaching the 5% significance level. Thus Hypothesis 1 is confirmed again.

Insert Tables 3

5.2 Endogeneity

This research investigates the effect of R&D narrative disclosures on the investment efficiency of the firms themselves and that of upstream peers in the supply chain in the following year. Therefore, the empirical results in the text do not suffer from endogeneity. To enrich the evidence supporting our results, a two-stage least squares analysis is conducted. We refer to Lo et al. (2017) and Lim et al. (2018) and apply the variables of corporate size ($SIZE_{i.t}$), years since establishment ($AGE_{i.t}$), debts ratio ($LEV_{i.t}$), price-to-book ratio ($PB_{i.t}$), return on assets ($ROA_{i.t}$), and dummy variable of net loss after tax ($LOSS_{i.t}$), to understand their effect on R&D narrative disclosures.

The hypotheses in the text are supported by the sensitivity analysis. Model 1 in Table 7 controls the issue of endogeneity by instrumental variables. This regression result shows that Readability 1 ($\overline{\text{READ1}}_{i,t-1}$) of R&D narrative disclosures is significantly and positively related with the corporate investment efficiency in the

following year ($INVEFF_{i,t}^{new}$), with a regression coefficient of 1.731, *t* value of 2.65, and significance level of 1%. The result of Model 2 shows a significant and positive relationship between $\overline{\text{READ2}}_{i,t}$ and $INVEFF_{i,t}^{new}$, with a regression coefficient of 2.465, *t* value of 2.5, and significance level of 5%. Hypothesis 1 of higher readability of R&D narrative disclosures in corporate annual reports increasing corporate investment efficiency is again confirmed. In sum, the empirical results for the main research questions show no endogeneity issue.

Insert Tables 4

6. Conclusions

Focusing on the 116 semiconductor companies in Taiwan and the sample period of 2010 to 2020, this study explores the effect of non-financial information quality provided by downstream companies (clients) on the investment anomaly and efficiency of upstream firms (suppliers). We find that higher readability of R&D narrative disclosures increases corporate investment efficiency. The content and readability of R&D narrative disclosures could alleviate investment asymmetry. As a result, investors are more likely to lower their demand for risk premiums and cost of equity. With reduced cost of capital, firms have stronger leverage for external financing to increase investment and investment efficiency.

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Table 1 Descriptive Statistics

Panel A: Hypothesis 1

Variable	Mean	Median	Std. Dev.	Min.	Max.
$INVEFF_{i,t}^{new}$	-4.774	-3.509	4.094	-15.139	-0.004
$READ1_{i,t-1}$	-8.186	-8.244	0.611	-9.120	-5.673
$READ2_{i,t-1}$	-2.252	-2.242	0.421	-2.977	-0.893
$SIZE_{i,t}$	15.373	15.164	1.591	13.171	21.739
$RDI_{i,t}$	13.472	8.335	17.875	0.540	202.922
$COD_{i,t}$	1.314	0.851	3.089	0.000	68.329
$COE_{i,t}$	7.690	7.687	2.952	1.609	17.725
$P/B_{i,t}$	2.000	1.515	2.297	0.680	41.480
$SlACK_{i,t}$	25.259	21.620	15.304	4.923	79.261
$TANG_{i,t}$	25.724	20.257	19.196	1.789	80.744
$CFO_{i,t}$	8.473	9.247	10.709	-13.033	49.974
$K\_Structure_{i,t}$	8.735	2.447	12.480	0.017	67.296
$OPCYCLE_{i,t}$	4.937	4.900	0.419	4.233	7.075
$BLOCK_{i,t}$	18.932	16.375	11.655	5.310	67.970
$INST_{i,t}$	39.521	34.684	24.605	7.130	95.450
$ROA_{i,t}$	3.511	5.090	9.029	-16.840	36.860
$LOSS_{i,t}$	0.285	0.000	0.451	0.000	1.000

Note: 1. Hypothesis 1 is tested by 1,128 samples and Hypothesis 2 has 2,648 samples. 2. $INVEFF_{i,t}^{new}$: corporate investment efficiency in year *t*; $READ1_{i,t-1}$: Readability 1 of R&D narrative disclosure of firm *i* in year *t*-1 (calculated by the natural logarithm of R&D narrative wordcounts in annual reports multiplied by (-1)); $READ2_{i,t-1}$: Readability 2 of R&D narrative disclosure of firm *i* in year *t*-1(measured by the fog index of R&D narrative paragraphs in annual reports multiplied by (-1)); $SIZE_{i,t}$: corporate size measured by natural logarithm of total assets of firm *i* in year *t*; $RDI_{i,t}$: R&D intensity of firm *i* in year *t* (%); $COD_{i,t}$: cost of debts of firm *i* in year *t* (%); $COE_{i,t}$: cost of equity of firm *i* in year *t* (%); $P/B_{i,t}$: price-to-book ratio of firm *i* in year *t*; $SLACK_{i,t}$: financial slack of firm *i* in year *t* (%); $TANG_{i,t}$: tangible assets intensity of firm *i* in year *t* (%);$CFO_{i,t}$: operating cash flow ratio of firm *i* in year *t* (%); $K\_Structure_{i,t}$: capital structure of firm *i* in year *t* (%); $OPCYCLE_{i,t}$: natural logarithm of operating cycles of firm *i* in year *t*; $BLOCK_{i,t}$: holding of major shareholders of firm *i* in year *t* (%); $INST_{i,t}$: holding of institutional shareholders of firm *i* in year *t* (%); $ROA_{i,t}$: return on assets of firm *i* in year *t* (%); $LOSS_{i,t}$: dummy variable of current net loss after tax. 3. All the continuous variables are winsorized by 5% and 95% to avoid the effect of extreme values.

Table 2 Effect of R&D Narrative Disclosures on Corporate Investment Efficiency

		Dependent Variable: $INVEFF_{i,t}^{new}$					
		Model 1			Model 2		
Independent Variable	Exp. sign	coef	*t* value	VIF	coef	*t* value	VIF
$Intercept$		-7.291***	-2.67		-9.312***	-4.03	
$READ1_{i,t-1}$	+	0.392**	1.98	1.092			
$READ2_{i,t-1}$	+				0.556*	1.93	1.101
Controlled Variables							
$SIZE_{i,t}$		0.589***	5.13	2.490	0.593***	5.15	2.496
$RDI_{i,t}$		-0.003	-0.41	1.407	-0.003	-0.37	1.409
$COD_{i,t}$		-0.002	-0.04	1.142	-0.002	-0.04	1.142
$COE_{i,t}$		0.004	0.06	2.546	0.006	0.09	2.551
$P/B_{i,t}$		-0.05	-0.91	1.172	-0.049	-0.9	1.173
$Slack_{i,t}$		-0.006	-0.63	1.639	-0.006	-0.66	1.643
$TANG_{i,t}$		-0.057***	-6.53	2.112	-0.057***	-6.53	2.113
$CFO_{i,t}$		0.04***	2.62	2.002	0.04***	2.59	1.999
$K\_Structure_{i,t}$		-0.005	-0.36	1.765	-0.004	-0.33	1.765
$OPCYCLE_{i,t}$		-0.117	-0.38	1.247	-0.119	-0.39	1.247
$BLOCK_{i,t}$		0.024**	2.03	1.446	0.024**	2.02	1.445
$INST_{i,t}$		-0.033***	-4.80	2.173	-0.033***	-4.76	2.167
$ROA_{i,t}$		-0.013	-0.54	3.709	-0.013	-0.53	3.711
$LOSS_{i,t}$		0.406	0.92	2.955	0.406	0.92	2.955
$YearFixed\ Effect$			Yes			Yes	
$Adjusted\ R^2$			9.81%			9.79%	
N			1,128			1,128	
$F-statistic$			6.11***			6.1***	

Note: 1. $INVEFF_{i,t}^{new}$: corporate investment efficiency of firm *i* in year *t*; $READ1_{i,t-1}$: Readability 1 of R&D narrative disclosure of firm *i* in year *t*-1 (measured by the natural logarithm of R&D narrative wordcounts in annual reports multiplied by (-1)); $READ2_{i,t-1}$: Readability 2 of R&D narrative disclosure of firm *i* in year *t*-1(measured by the fog index of R&D narrative paragraphs in annual reports multiplied by (-1)). For the definitions of other control variables please refer to Table 1. 2. *, **, and *** indicate significance levels of 10%, 5%, and 1% respectively in the two-tailed test. 3. N is the sample number. 4. No multicollinearity among independent variables in the models exists, as their VIF values are all less than 10.

Table 3 Effect of Readability of R&D Disclosures on Corporate Investment Efficiency – Average Readability from Previous Three Years

		Dependent Variable: $INVEFF_{i,t}^{new}$					
		Model 1			Model 2		
Independent Variable	Exp. sign	coef	*t* value	VIF	coef	*t* value	VIF
$Intercept$		-7.209**	-2.31		-9.863***	-3.76	
$READ1_{i,avg}$	+	0.5**	2.16	1.091			
$READ2_{i,avg}$	+				0.665**	1.97	1.100
Controlled Variables							
$SIZE_{i,t}$		0.696***	5.19	2.689	0.699***	5.2	2.696
$RDI_{i,t}$		-0.004	-0.47	1.404	-0.004	-0.44	1.405
$COD_{i,t}$		0.006	0.15	1.136	0.006	0.15	1.136
$COE_{i,t}$		-0.044	-0.55	2.711	-0.041	-0.51	2.718
$P/B_{i,t}$		-0.075	-1.17	1.190	-0.074	-1.16	1.191
$Slack_{i,t}$		-0.009	-0.82	1.586	-0.01	-0.86	1.589
$TANG_{i,t}$		-0.053***	-5.27	2.083	-0.053***	-5.25	2.087
$CFO_{i,t}$		0.035*	1.96	2.048	0.034*	1.92	2.046
$K\_Structure_{i,t}$		-0.012	-0.81	1.672	-0.011	-0.78	1.674
$OPCYCLE_{i,t}$		-0.112	-0.32	1.254	-0.114	-0.32	1.254
$BLOCK_{i,t}$		0.025*	1.83	1.432	0.024*	1.81	1.431
$INST_{i,t}$		-0.037***	-4.68	2.198	-0.036***	-4.61	2.189
$ROA_{i,t}$		-0.002	-0.08	3.628	-0.003	-0.09	3.630
$LOSS_{i,t}$		0.588	1.16	2.875	0.591	1.16	2.875
$YearFixed\ Effect$			Yes			Yes	
$Adjusted\ R^2$			9.40%			9.32%	
N			909			909	
$F-statistic$			5.28***			5.24***	

Note: 1. $INVEFF_{i,t}^{new}$: corporate investment efficiency in year *t*; $READ1_{i,avg}$: averaged readability of R&D narrative disclosures of firms in previous three years as calculated by the average of the natural logarithm of R&D narrative wordcounts in every year multiplied by (-1); $READ2_{i,avg}$: averaged readability of R&D narrative disclosures of firms in previous three years as measured by the average of the fog index of R&D narrative paragraphs in every year multiplied by (-1). The definition of other controlled variables please refer to Table 1. 2. *, **, and *** indicate significance levels of 10%, 5%, and 1% respectively in the two-tailed test. 3. N is the sample number. 4. No multicollinearity among variables in the models as the VIF values are all less than 10.

Table 4 Effect of Readability of R&D Disclosures on Corporate Investment Efficiency – Issue of Endogeneity

		Dependent Variable: $INVEFF_{i,t}^{new}$					
		Model 1			Model 2		
Independent Variable	Exp. sign	coef	*t* value	VIF	coef	*t* value	VIF
$Intercept$		3.376	0.60		-5.764**	-1.99	
$\overline{\text{READ1}}_{i,t-1}$	+	1.731***	2.65	1.443			
$\overline{\text{READ2}}_{i,t-1}$	+				2.465**	2.5	1.580
Controlled Variables							
$SIZE_{i,t}$		0.58***	5.07	2.479	0.614***	5.31	2.526
$RDI_{i,t}$		-0.007	-0.84	1.430	-0.006	-0.8	1.428
$COD_{i,t}$		-0.013	-0.31	1.154	-0.012	-0.29	1.153
$COE_{i,t}$		0.003	0.06	2.542	0.004	0.07	2.544
$P/B_{i,t}$		-0.041	-0.75	1.179	-0.039	-0.71	1.184
$Slack_{i,t}$		-0.004	-0.39	1.634	-0.004	-0.43	1.633
$TANG_{i,t}$		-0.056***	-6.45	2.078	-0.056***	-6.46	2.080
$CFO_{i,t}$		0.042***	2.73	2.011	0.041***	2.71	2.009
$K\_Structure_{i,t}$		-0.001	-0.10	1.782	-0.001	-0.08	1.787
$OPCYCLE_{i,t}$		-0.089	-0.29	1.246	-0.09	-0.29	1.246
$BLOCK_{i,t}$		0.024**	2.04	1.444	0.024**	2.03	1.444
$INST_{i,t}$		-0.031***	-4.47	2.173	-0.031***	-4.47	2.174
$ROA_{i,t}$		-0.008	-0.31	3.757	-0.008	-0.34	3.753
$LOSS_{i,t}$		0.375	0.85	2.958	0.389	0.88	2.956
$YearFixed\ Effect$			Yes			Yes	
$Adjusted\ R^2$			10.06%			10.00%	
N			1,128			1,128	
$F-statistic$			6.25***			6.22***	

Note: 1. $INVEFF_{i,t}^{new}$: corporate investment efficiency in year *t*; $\overline{\text{READ1}}_{i,t-1}$ and $\overline{\text{READ2}}_{i,t-1}$: fitted values based on the regression coefficients in the main section of analysis; $\overline{\text{READ1}}_{i,t-1}$ is calculated by the natural logarithm of R&D narrative wordcounts in annual report multiplied by (-1); $\overline{\text{READ2}}_{i,t-1}$ is measured by the fog index of R&D narrative paragraphs in annual report multiplied by (-1). For the definition of other control variables please refer to Table 3. 2. *, **, and *** indicate significance levels of 10%, 5%, and 1% respectively in the two-tailed test. 1. N is the sample number. 4. No multicollinearity among variables in the models exist, as their VIF values are all less than 10.