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The Impact of Environmental, Social, and Governance Disclosure on Research and Development Investment: The Mediating Role of External Financing

Mahdi Saghafi*, Maryam Sadat Tabatabaeian, Eisa Haddadi

Department of Accounting, Payame Noor University, Tehran, Iran

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Abstract

This study investigates the relationship between environmental, social and governance (ESG) disclosure and firms' research and development (R&D) spending, with a focus on the mediating function of external financing. The research employs a panel data research design using firm-level financial data. The sample includes 152 enterprises that are listed on the Tehran Stock Exchange throughout the period 2015-2024. Firm-level data on financial and ESG-related issues were acquired from public filings in the CODAL database. The panel data were analyzed in Stata. The results implied that more R&D spending is linked to better ESG disclosure. Moreover, external funding positively affects R&D investment and somehow mediates the relationship between ESG disclosure and R&D expenditure. The study presented an integrated analysis of the relationship between ESG disclosure and enterprises' innovation-related investment decisions by investigating ESG dimensions with external finance. The results added to the expanding literature on ESG and business innovation by identifying the financial pathways via which ESG disclosure can affect long-term investment behavior.

Keywords:
Environmental, External Financing, Research and Development Investment, Social Governance (ESG) Disclosure

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*Corresponding Author: Mahdi Saghafi
Email: saghafi.mahdi@pnu.ac.ir
Tel: 09151605648
ORCID: 0000-0001-6329-1202

1. Introduction

Firms can raise capital through several channels, including short-term and long-term debt instruments as well as equity financing (Campello and Giambona, 2013). In well-functioning capital markets, firms are generally expected to access external financial resources at reasonable cost (Demirguc-Kunt and Maksimovic, 1996). The availability and structure of this financing are particularly important for long-term, uncertain investments, among which R&D occupies a central position.

R&D is the investment of firms in the generation of new knowledge and the conversion of this information into novel goods, processes and technology. In general, R&D investment has been considered an important determinant of business growth and economic development, given its importance for innovation and long-run competitiveness (Aghion and Howitt, 1992; Pitt et al., 2013). R&D is strategically important but hard to finance due to high unpredictability, a long investment horizon and few collateralizable assets. These features exacerbate information asymmetry and funding constraints, especially in emerging capital markets (Hall, 2007; Sasidharan et al., 2015). These financing challenges make transparent corporate disclosure especially important in reducing information asymmetry and facilitating access to external capital.

ESG disclosure has become an important source of information and a strategic factor shaping firms' interactions with capital markets. ESG indicators measure the ability of a company to achieve sustainable development objectives by taking into account its social and governance responsibilities (Jin et al., 2024). More ESG disclosure by firms may minimize information asymmetry and perceived risk, therefore decreasing the probability of financial distress and boosting stakeholders' capacity to assess business performance (Zhang et al., 2020). ESG disclosure is the transparency, completeness and verifiability of the information disclosed to external stakeholders, whereas ESG performance is the actual ESG results achieved by the organization. Accordingly, the theoretical arguments developed in this study focus exclusively on ESG disclosure, as the informational role of disclosure differs conceptually from the operational outcomes reflected in ESG performance.

Stakeholder theory holds that firms should create value for shareholders and other stakeholders. Transparent ESG disclosure helps to improve stakeholder relationships by eliminating information asymmetry, promoting responsibility and creating a platform for criticism and debate. There is growing empirical evidence supporting a beneficial relationship between ESG disclosure and financial performance, usually explained by reducing information asymmetry, lower perceived risk and better access to external capital. For example, An et al. (2025) find that ESG disclosure of information improves firm value by alleviating financing limitations. Similarly, Hamdouni (2025) finds that ESG disclosures enhance value by reducing the cost of capital, while Ruan et al. (2024) find that ESG information disclosure facilitates corporate green innovation. Other research has found that ESG disclosure minimizes market information asymmetry (Siew et al., 2016), reduces the cost of debt (Feng and Wu, 2023) and improves audit quality and transparency (Asante-Appiah, 2020). Strong ESG disclosure may reduce the perceived risk and increase financial transparency, hence facilitating firms' access to external financing.

The links among ESG disclosure, risk, and investment decisions are especially relevant to R&D. R&D investment is a key driver of long-term growth, yet it is highly sensitive to financing constraints and economic cycles (Lee and Choi, 2011). Under economic stress or liquidity shocks, corporations tend to emphasize short-term investments and scale back their R&D spending, especially when they face difficulty in raising external capital. This procyclical tendency is consistent with the R&D initiatives being characterized by high sunk costs and large losses if projects are halted or abandoned (Kim and Choi, 2020). Thus, the ability of enterprises to sustain R&D expenditure vitally depends upon stable access to external financing.

ESG disclosure may therefore influence R&D investment both directly and indirectly. Companies under economic hardship or facing liquidity shocks are prone to shift their focus toward short-term investments and reduce their R&D expenditure, particularly if they find it hard to secure external funding. Such procyclicality is consistent with the R&D initiatives being high in sunk costs and with big losses if projects are stopped or abandoned (Kim and Choi, 2020). It follows that the ability of firms to continue R&D expenditure is critically dependent on stable access to external financing. Prior studies suggest that both debt and equity financing can alleviate financial constraints and provide resources for long-term investments such as R&D. External financing may thus be directly associated with R&D investment and may also provide a channel through which ESG disclosure influences firms' innovation activities. Although previous studies have documented the direct effects of ESG disclosure on corporate outcomes and innovation-related activities, limited attention has been devoted to the financing mechanisms through which ESG disclosure influences firms' R&D investment. By simultaneously examining ESG disclosure, external financing, and R&D investment in the Iranian capital market, this study addresses this gap and extends the literature with evidence from an underexplored institutional setting. This gap is particularly relevant in emerging economies, where enterprises are generally more vulnerable to financing limitations and information asymmetries, and hence disclosure procedures are more likely to be significant for the determination of financing and investment decisions. Iran provides a distinctive institutional setting for examining the ESG disclosure–R&D relationship. As one of the largest capital markets in the region, the Tehran Stock Exchange operates within an environment characterized by relatively high information frictions and financing challenges. Examining the proposed relationships in this context therefore extends the existing literature by providing evidence from an underexplored institutional environment.

Therefore, the current study aims to answer the following research question: How does ESG disclosure affect firms' R&D spending and to what extent does external finance moderate this relationship? This paper contributes to the literature on corporate finance, sustainability and innovation by explicitly integrating external financing into the ESG-R&D paradigm. A key empirical issue in the study of the relationship between ESG disclosure and R&D expenditure is the possibility of endogeneity due to the omission of firm-specific features and the fluid nature of corporate decision-making. While the theoretical framework presented in this study predicts that ESG disclosure improves firms' financing conditions and hence encourages R&D investment, the empirical evaluation has to pay particular attention to potential sources of bias that may alter the observed correlation. Besides the theory-based hypotheses, the study adopts a number of methodological approaches to improve the reliability of the estimated correlations and to reinforce the robustness of the empirical results.

The findings of this study have implications for policymakers, regulators, and standard setters concerned with promoting sustainable corporate behavior and efficient capital markets. ESG practices improve financial disclosure and market resilience (Albuquerque et al., 2019; Baron, 2007; Fatemi, 2015; Lins, 2017; Su and Xue, 2024). ESG's function in R&D investment stability and innovation risk mitigation is understudied. ESG disclosure is linked to green innovation (Lin et al., 2021; Wang et al., 2023; Zhai et al., 2022; Zheng et al., 2023) and sustained R&D investment is crucial for long-term growth (Cohen and Levinthal, 1989). Examining the financing channel through which ESG disclosure affects R&D investment provides valuable insights.

The rest of this paper is structured as follows. The next section discusses the foundations of theory and hypothesis development. Next, the methodology section is presented, where the empirical models, data and measurement of variables are explained. The following section presents the empirical results and the concluding section discusses the results and their policy and management implications.

2. Theoretical background

This study is theoretically grounded in stakeholder theory, signaling theory, information asymmetry theory and pecking order theory to explain the effect of ESG disclosure on firms' R&D expenditure. Stakeholder theory shows how transparent ESG disclosure strengthens ties with external stakeholders; signaling theory shows how disclosure offers reliable information on firm quality; and information asymmetry and pecking order theories show how greater transparency helps in accessing external finance. These complementary perspectives form the conceptual underpinning of the direct and indirect exchanges detailed here.

2.1. ESG disclosure and R&D Investment

ESG practices have shifted from voluntary disclosure initiatives to a core component of business sustainability strategy (Hou et al., 2025; Yi et al., 2024; Azadzanjani et al., 2025). In capital markets with knowledge asymmetry, enterprises are generally subjected to higher risk premia and increased costs of external funding (Myers, 1977). Hence, enterprises, particularly in less efficient financial markets, tend to rely largely on internal funds, mostly in the form of operating revenues, to finance R&D operations (Czarnitzki et al., 2011).

This reliance on internal financing renders R&D investment highly sensitive to fluctuations in market conditions. Decreases in sales revenues or profitability might cause shortages in internal finance and thus compel enterprises to cut down or delay R&D investments (Kang et al., 2017). Lin et al. (2021) state that R&D projects are long-term, uncertain and irreversible, and that such disruptions may decrease the innovation efficiency and harm the competitive position of enterprises. Therefore, how corporations may stabilize R&D expenditure, in particular through access to external financing, has become a fundamental subject in the innovation and corporate finance literature.

Strong ESG disclosure has been shown to reduce perceived firm risk and improve transparency, thereby lowering the cost of external financing and enhancing firms' access to capital markets (Dhaliwal et al., 2011; Chen et al., 2023). However, ESG disclosure may alleviate financing limitations (Hamdouni, 2025), help minimize firms' dependence on internally produced cash, and shield R&D investment from short-run market volatility. From this perspective, ESG disclosure may contribute to maintaining R&D investment over time.

Stakeholder theory is a useful lens for understanding why organizations with extensive, high-quality ESG disclosure may be better positioned to support long-term investment. This idea argues that corporations are accountable to shareholders and a broad range of other stakeholders, including employees, customers, regulators and local communities. Three primary channels through which transparent and consistent ESG disclosure enhances stakeholder trust include: (1) decreasing information asymmetry between the firm and its stakeholders; (2) signaling a verifiable commitment to accountability; and (3) providing a forum for feedback and ongoing engagement. Consistent ESG disclosure builds relationships among stakeholders, organizational legitimacy and company reputation. These variables also lead to a more stable institutional framework conducive to long-term strategic investments such as R&D, which is characterized by high uncertainty, long-term time horizons, and delayed returns.

Within stakeholder theory, disclosure is an important means by which firms communicate their values, commitments, and strategic priorities to external stakeholders. Although real ESG results may not be directly seen, open disclosure might affect how stakeholders view the company by showing accountability, decreasing uncertainty, and indicating a willingness to address stakeholders' concerns. Thus, enterprises that disclose significant ESG-related information may obtain more positive reactions from investors, creditors and other stakeholders, and consequently improve their

access to resources necessary to finance long-term expenditures such as R&D. Empirical evidence indicates that firms with better ESG disclosure are more willing and able to invest in innovative activities, since transparency-driven stakeholder support helps to mitigate the risks of persistent R&D investment (Ruan et al., 2024; Siew et al., 2016).

According to signaling theory, a signal is credible when (a) it is costly for the sender to produce, and (b) it cannot be easily imitated by low-quality senders. In the context of ESG disclosure, while merely checking boxes may not be costly, high-quality, verifiable disclosure (e.g., quantified targets, progress reports, negative information) can be costly. Poorly performing firms are reluctant to disclose precise, verifiable information because it may expose them to legal and reputational risks. Thus, disclosure quality (not mere presence) acts as a signal of managerial quality. In settings characterized by information asymmetry between managers and external capital providers, transparent ESG reporting reduces uncertainty and enhances the evaluability of firms' investment projects. This signaling effect can reduce the cost of capital and facilitate access to external financial resources, enabling more effective allocation of funding to R&D operations (Hamdouni, 2025; Feng and Wu, 2023). Therefore, ESG disclosure should affect R&D investment both directly, by increasing stakeholders' confidence and transparency, and indirectly, by providing better financing circumstances and reducing knowledge asymmetry.

Recent empirical findings support this argument. An et al. (2025) found that publication of ESG information improves firm value by relieving financing limitations, with consequences for firms' ability to sustain long-term investment. Ruan et al. (2024) found that ESG information disclosure can encourage corporate green innovation, indicating that disclosure is associated with innovation-related expenditure. Previous studies have mainly examined the relationship between ESG performance and innovation outputs (e.g., patents or green innovation indicators) (Lin et al., 2021; Zhai et al., 2022; Zheng et al., 2023). This study, however, emphasizes the role of ESG disclosure as a unique information mechanism in stabilizing R&D investment. This methodology responds to recommendations in the literature for examining the fundamental processes via which ESG disclosure influences business performance and innovation outcomes (Gillan et al., 2021).

An alternative view is that the effect of ESG disclosure may depend on whether disclosures are substantive or symbolic in character. Genuine commitments to sustainability are reflected in substantive ESG disclosures that give stakeholders credible information about a firm's policies, practices and long-term goals. Alternatively, symbolic ESG disclosures might be adopted more for legitimacy reasons or in response to stakeholder pressures, without necessarily reflecting matching organizational activities. ESG information may not have a significant impact on a firm's access to financial resources or its R&D expenditure in such instances because it may only give minimal informational value to investors and creditors. However, in line with signaling theory and the information asymmetry paradigm, better quality and more transparent ESG disclosure can increase credibility, reduce information asymmetry and improve stakeholders' confidence. Hence, this study expects that ESG disclosure is positively related to firms' R&D investment.

Collectively, these theoretical lenses explain how ESG disclosure can affect firms' R&D spending directly by increasing transparency and stakeholder confidence and indirectly by improving access to external financing. Based on this integrated framework, the next sections establish the specific assumptions on external financing and its mediating role. Thus, the study provides the following hypothesis:

H1: *ESG disclosure is positively associated with firms' R&D investment.*

2.2. ESG disclosure and external financing

The link between ESG disclosure and external financing can be primarily elucidated by the

information asymmetry and pecking order theories within the integrated theoretical framework outlined above. It is theoretically aligned with the stakeholder and signaling perspectives discussed earlier. According to the pecking order theory, organizations prefer to use internal funds over external funding due to information asymmetry between managers and external capital suppliers. When this disparity is extreme, the cost of external financing increases and firms are more constrained in obtaining loan and equity capital. Therefore, funding decisions depend on enterprises' investment needs as well as on the perceived transparency and credibility by investors and creditors.

Effective ESG disclosure may reduce information asymmetry by improving the quality of nonfinancial disclosure and overall organizational openness. High-quality ESG reporting allows market players to analyze organizations' ESG risks, therefore lowering uncertainty over future cash flows and long-term viability (Ding et al., 2024). That reduced sense of risk can lead to lower risk premia, better terms on credit contracts and stronger positions for corporations in both the debt and equity markets. Empirical research indicates that enterprises with more extensive and verifiable ESG disclosure enjoy fewer financing limitations and a lower cost of capital, boosting their ability to access external financial resources (Hao and Wu, 2024; Xu et al., 2025).

Signaling theory can also be employed to clarify the function of ESG disclosure in attracting external financing. From this perspective, voluntary ESG disclosures serve as a reliable indicator of managerial quality and long-term strategy orientation and commitment to sustainable wealth development. Such signals lessen the uncertainty of investors and creditors and boost trust in the firm's ability to manage risk and provide steady returns in situations when information asymmetries exist. Therefore, financial markets are more likely to respond positively to companies that have excellent ESG disclosure, allowing them to have better access to external financing through debt issuance and equity markets (Feng and Wu, 2023; Zhao et al., 2025).

Financing restrictions can also be exacerbated by agency conflicts between managers and stakeholders, due to higher monitoring expenses and perceived risk (Chae et al., 2009). While previous research has stressed the significance of internal cash flow for financing long-term investments such as R&D by enterprises (Brown and Petersen, 2011; Himmelberg and Petersen, 1994), very little emphasis has been paid to the function of external finance. But there is some evidence from emerging markets that foreign financing can play a bigger role. For example, García-Sánchez et al. (2019) found a positive and statistically significant association between corporate social responsibility disclosure, a type of nonfinancial disclosure, and firms' access to capital and money markets.

ESG disclosures can also influence external finance by impacting stakeholder perceptions and expectations. Investment projects with uncertain and long-term payoffs require stakeholders to accept delayed returns and higher exposure to risks. Sustainability reporting can boost a company's reputation and increase stakeholder trust, thereby helping to align stakeholder interests and reduce opposition to external finance (El Ghoul et al., 2011; Jo and Na, 2012). This reputational channel is particularly important in economies when disclosure norms are weak and institutional constraints lower investor confidence. In such an environment, ESG transparency is an efficient way to ease financing limitations and reduce capital costs (Li et al., 2024).

Overall, ESG disclosure is expected to help organizations get external financing, although the debt and equity financing channels are different, since creditors and shareholders have different views and goals when assessing ESG-related information.

Lenders in the debt markets focus mainly on the risk of default, ability to repay and financial soundness of the firms. High-quality ESG disclosure decreases asymmetry of information about firms' risk management procedures and long-term sustainability, allowing lenders to better assess credit risk. Consequently, enterprises with a higher level of transparency in their ESG disclosure can

access loan funding at more favorable terms and with a lower degree of borrowing limits.

But for equity investors, the contractual commitments to pay are less important than the long-term growth potential, future cash flows and the opportunity to build value. The disclosure of ESG can help to strengthen the confidence of investors, market valuation and access to equity capital from investors seeking long-term investment opportunities by providing greater openness about the strategic orientation, sustainability commitments and long-term risk management of organizations.

These theoretical arguments suggest that strong ESG disclosure improves firms' access to external financing by reducing information asymmetry, mitigating agency conflicts, and enhancing stakeholder trust. Moreover, these effects may operate through distinct financing channels, including both debt and equity markets. Accordingly, the following hypotheses are proposed:

H2: ESG disclosure is positively associated with firms' access to external financing through debt.

H3: ESG disclosure is positively associated with firms' access to external financing through equity issuance.

2.3. External financing, R&D investment, and the mediating role of ESG

Following the preceding theoretical arguments, external financing may serve as the mechanism through which the informational benefits of ESG disclosure are translated into firms' long-term innovation investment. R&D investment differs from most other forms of corporate investment due to its high uncertainty, long time horizon, and limited collateral value. These characteristics make R&D projects particularly sensitive to financing constraints and liquidity conditions. Firms with restricted access to external funding tend to depend on internally generated funds to back up the R&D efforts. In consequence, variations in internal financial flows, especially those related to changes in sales revenues, may result in severe volatility in R&D investments, such as project delays, pauses or cancelations (Brown and Petersen, 2011; Czarnitzki et al., 2011).

Empirical evidence shows that R&D expenditures are more closely linked to market performance and sales revenues than to accounting profits, highlighting the dependence of innovation investment on internal liquidity (Ito and Pucik, 1993; Coad and Rao, 2010). When sales decline, reduced internal cash flows constrain firms' ability to sustain R&D spending, whereas periods of sales growth tend to coincide with increased R&D investment. R&D operations are prone to market shocks due to this dependence on internal finance, and this increases the procyclicality of investment (Kang et al., 2017). Thus, improving the external finance availability can decrease the susceptibility of R&D investment to the market conditions in the short term and promote the stability of R&D investment in the temporal dimension.

However, debt and equity financing can help to reduce these limits by providing organizations with additional liquidity to undertake long-term, innovation-oriented expenditures. Debt financing provides a way for corporations to smooth R&D spending over the economic cycle, whereas equity financing can be used to finance high-risk, long-horizon initiatives that need not be repaid immediately. Accordingly, greater access to external financing is expected to have a positive effect on firms' R&D investment capacity.

H4: External financing through debt is positively associated with firms' R&D investment.

H5: External financing through equity issuance is positively associated with firms' R&D investment.

Based on the ideas in the previous sections, ESG disclosure could affect R&D investment indirectly through enhancing firms' access to external financing. Companies with good ESG disclosure tend to be more transparent, better at risk management, and have better ties with their stakeholders, which reduces the risk perceived by investors and creditors (Goss and Roberts, 2011; Eccles et al., 2014; Lian et al., 2023). As discussed earlier, these characteristics facilitate access to

both debt and equity financing and reduce firms' reliance on internal funds.

Specifically, the indirect relationship between ESG disclosure and R&D investment is expected to operate through improvements in firms' financing conditions. More open and credible ESG disclosure can minimize information asymmetry and the perception of risk by investors and creditors, and as such, reduce the cost of both debt and equity financing, and alleviate external funding limitations. Better external capital availability may improve the financial flexibility of organizations and allow them to undertake long-term and high-risk innovation projects that could otherwise be difficult to finance only from internal sources. In order to convert the informational benefits of ESG disclosure into persistent R&D investment, external financing is the main vehicle.

Strong ESG disclosure helps organizations to keep stable R&D investment when market demand falls or economic conditions are not favorable by relaxing financing limits. Furthermore, access to external finance might help to avoid excessive expansions and contractions in R&D spending during the business cycle, hence enabling more consistent innovation strategies (Chen et al., 2025). Therefore, external finance is likely to be the main transmission channel through which the informational benefits of ESG disclosure are transformed into firms' long-term R&D expenditure. Therefore, the following mediation ideas are proposed:

H6: External financing through debt mediates the relationship between ESG disclosure and firms' R&D investment.

H7: External financing through equity issuance mediates the relationship between ESG disclosure and firms' R&D investment.

The theory of the study proposes that the disclosure of environmental, social, and governance (ESG) has an impact on R&D expenditure of enterprises via two channels, directly and indirectly via improved access to external financing. While these connections are founded on signaling theory, stakeholder theory and information asymmetry considerations, empirical examination of the hypothesized implications requires taking into account possible estimation problems connected with firm-level panel data. Therefore, the empirical analysis incorporates appropriate econometric methods and robustness tests to assess whether the observed relationships are in accordance with the theoretical predictions derived in this work.

3. Research methodology

3.1. Research design

This study employs a quantitative panel data research design to examine the relationships among ESG disclosure, external financing, and R&D investment. Because the data are organized as a firm-level panel, potential endogeneity may arise from unobservable firm characteristics that simultaneously influence ESG disclosure, external financing decisions, and R&D investment. To mitigate these concerns, the empirical analysis incorporates a comprehensive set of firm-level control variables and employs panel-data estimation techniques selected on the basis of Chow and Hausman specification tests.

The choice between fixed-effects and random-effects estimators was based on the Chow and Hausman specification tests, together with the underlying economic characteristics of each model. Fixed effects were employed when unobserved firm-specific heterogeneity was likely to be correlated with the explanatory variables, whereas random effects were used otherwise. Furthermore, lagged measures of external financing are employed in the mediation models because financing decisions are expected to influence firms' R&D investment with a time lag rather than immediately. This specification better reflects the temporal ordering implied by the mediation framework while reducing simultaneity concerns.

The analysis uses robust standard errors throughout to correct for heteroskedasticity and serial correlation. These approaches together improve the dependability of the calculated connections and lower the probability that the results are driven by unobserved firm-specific factors.

3.2. Population, sample, and study period

The study population comprises all companies listed on the Tehran Stock Exchange (TSE). The study period covers the fiscal years 2015–2024. The research sample was selected from among TSE-listed enterprises according to the screening criteria described in Table 1. These criteria are helpful to ensure data continuity, comparability between enterprises and conformity with previous studies carried out in the Iranian capital market.

Table 1. Sample Selection Procedure

Description	Number
Total listed companies in 2024	452
Less: Companies with fiscal year-end other than 19 March	(119)
Less: Investment companies, banks, and insurance firms	(123)
Less: Companies that changed their fiscal year	(22)
Less: Companies with trading suspension exceeding six months	(36)
Final research sample	152

After applying these restrictions, 152 firms were selected as the final statistical sample, yielding a balanced panel of firm-year observations over the study period.

3.3. Variable measurement

3.3.1. Dependent variable: R&D investment (R&D)

Corporate R&D investment is measured as the ratio of R&D expenditures to average total assets, following Saharti (2025) and Fu et al. (2024). This measure controls for firm size effects and facilitates comparability across firms with heterogeneous scales of operation. R&D expenditure data were manually collected from firms' audited annual financial statements and the accompanying notes thereto available on the CODAL website.

3.3.2. Mediating variable: external financing (ExterF)

External financing is measured using two indicators, as proposed by Eskandar et al. (2015):

1. Percentage change in common equity, representing external financing through equity issuance;
2. Percentage change in financial debt, representing external financing through borrowing.

To mitigate potential simultaneity concerns between financing decisions and R&D investment, external financing variables are measured with a one-year lag relative to the dependent variable. Consistent with previous studies, changes in common equity are used as a proxy for equity-based external financing. While changes in equity may also reflect retained earnings, revaluation adjustments, or other accounting events, this measure has been widely employed in the literature as an observable indicator of firms' reliance on equity financing when direct data on net equity issuance are not consistently available. Therefore, the results should be interpreted as reflecting equity-based financing capacity rather than a pure measure of new share issuance.

3.3.3. Independent variable: ESG disclosure

The independent variable is ESG disclosure, measured using the checklist developed by Siew et al. (2016), Ng and Rezaee (2015) and Khotanlou et al. (2026), which has been adapted to the Iranian business environment. Each disclosure item was coded dichotomously, with a value of 1 if the item was disclosed and 0 otherwise. All items were equally weighted, and the ESG disclosure index was

calculated by subtracting the total weakness score from the total strength score and dividing the result by the total number of checklist items. Data for this variable were collected through content analysis, as detailed in Table 2, from the explanatory notes and the board of directors' activity reports presented to the annual general meeting of shareholders. Although this index captures ESG disclosure rather than underlying performance, prior literature suggests that disclosure quality itself plays a critical role in reducing information asymmetry and alleviating financing constraints.

The content analysis procedure followed the coding framework established in prior ESG disclosure studies and adapted to the Iranian institutional environment. Each disclosure item was evaluated using predefined coding criteria and scored consistently across all sample firms. The same coding protocol was applied across all sample firms using information disclosed in the explanatory notes and board of directors' reports. The use of a standardized checklist adopted from prior validated studies enhances the consistency, comparability, and reliability of the ESG disclosure measure.

3.3.4. Control variables

Consistent with prior empirical studies, the following firm-level variables are included as controls:

- Firm Size (SIZE): Natural logarithm of total assets.
- Return on Assets (ROA): Earnings before interest and taxes divided by total assets.
- Cash Flow from Operations (CFO): Operating cash flows scaled by total assets.
- Sales Growth (Growth): Annual percentage change in sales.
- Institutional Ownership (IOWN): Ratio of shares held by institutional investors to total outstanding shares.
- Firm Value (MTB): Ratio of market value of assets to book value of assets.
- Firm Age (Age): Natural logarithm of firm age.

4. Findings

4.1. Descriptive statistics

Table 3 presents descriptive statistics for the variables included in the empirical analysis. The sample consists of 1,520 firm-year observations, corresponding to 152 firms observed over the period 2015–2024. For each variable, the table presents the mean, standard deviation, minimum, and maximum values.

4.2. Results of Hypothesis 1: ESG disclosure is positively associated with firms' R&D investment.

The results strongly support Hypothesis 1. ESG disclosure has a positive and significant impact on corporate R&D expenditure ($\beta = 0.410$, $p < 0.01$), which suggests that organizations with higher ESG transparency invest more resources in long-term innovative activities. The coefficient size shows that increases in ESG disclosure are connected with a substantial rise in R&D intensity, which reflects the strategic importance of ESG in enabling innovation-oriented investment decisions.

Table 2. ESG Disclosure Checklist

	Strengths	Weaknesses
Environmental Indicators	1. Eco-efficient products and services (manufacturing environmentally sound and energy-efficient products) 2. Pollution prevention (the company has programs for preventing severe pollution, including emission reduction and toxic substance reduction programs). 3. Recycling (the company uses recycled materials as raw inputs in its production	1. Hazardous products (the company operates in a high-risk industry sector for hazardous products: chemicals and oil, leather and textiles, mining and basic metals production, paper and printing, and paints and cleaning agents. 2. Legal issues (payment of fines for environmental issues and problems caused by the company). 3. Ozone-depleting chemicals (the company is among the producers of ozone-depleting chemical

	processes, or is a primary actor in the recycling industry). 4. Clean energy (the company has undertaken significant measures to reduce impact on climate change and air pollution through the use of renewable energy and clean fuel, or through energy efficiency and conservation). 5. Receipt of environmental awards and certificates of recognition. 6. Property, plant, and equipment (the company maintains property, plant, and equipment with high environmental performance standards for its industry). 7. Management systems (acquisition of ISO 14001, ISO 50001, and ISO 28001 certifications for the company's management systems).	substances). 4. Agricultural chemicals (the company is a producer of agricultural chemicals, i.e., pesticides or chemical fertilizers, or a producer of their raw materials). 5. Climate change (the company causes climatic and weather change. The company derives significant revenue from the sale of coal or oil and their refined products, or derives significant revenue indirectly from the combustion of coal or oil and their derivative products).
Social Indicators	1. Domestic or foreign charitable activities (if the company allocates a portion of net profit before tax to charitable causes). 2. Implementation of innovative programs (allocation of funding to support non-profit companies and other companies under adverse economic conditions) 3. Housing support programs (housing assistance programs at the corporate and national levels). 4. Educational support programs (the company has a support program for primary, secondary, and higher education, or organizes a youth vocational training program). 5. Sports support programs (the company has a support program for sports at the corporate, provincial, and national levels). 6. Ratio of female executive managers (the company employs female executive managers). 7. Ratio of total number of employees to net sales. 8. Work/life benefits (off-company benefits for children, the elderly, or leisure activities). 9. Ratio of female employees to total number of company employees. 10. Ratio of research and development (R&D) expenditures to net sales.	1. Negative economic effects (companies that experience legal issues regarding water, land, waste disposal, or other issues affecting the community's livelihood, taxation, or asset value). 2. Tax issues (the tax file is pending before the Tax Dispute Resolution Board). 3. Court proceedings (litigation related to employees, insurance, and other matters).
Governance Indicators	1. Financial expertise ratio of board members. 2. Board independence ratio. 3. Frequency of board meetings. 4. Remuneration (if the company has paid bonuses or meeting attendance fees to senior executives during the fiscal year, and such amounts are reflected in the audited financial statements). 5. Percentage of major shareholders' ownership. 6. Consecutive tenure ratio of the board chair. 7. Consecutive tenure ratio of the CEO. 8. Consecutive tenure ratio of the external auditor. 9. Board size.	1. Executive status of the board chair. 2. Non-executive status of the CEO. 3. Accounting concerns (the company has received an adverse audit opinion). 4. Ratio of related-party transactions to net sales.

Table 3. Descriptive statistics of study variables

Variable	Symbol	Obs.	Mean	Std. Dev.	Min	Max
R&D investment	RD	1,520	0.001	0.005	0.000	0.094
External financing (debt)	ExterFLEV	1,520	0.352	0.468	−0.318	2.499
External financing (equity)	ExterFStock	1,520	0.468	1.098	0.000	8.62
ESG disclosure	ESG	1,520	0.541	0.138	0.083	0.833
Firm size	Size	1,520	15.259	1.739	11.128	21.899
Return on assets	ROA	1,520	0.193	0.167	−0.581	0.660
Operating cash flows	CFO	1,520	0.122	0.139	−0.398	0.687
Sales growth	Growth	1,520	0.387	0.457	−0.397	2.893
Institutional ownership	IOWN	1,520	0.660	0.202	0.055	0.954
Firm age	Age	1,520	3.655	0.352	2.639	4.276
Firm value	MTB	1,520	2.868	2.615	0.622	25.589

Table 4. Estimation results for Hypothesis 1

$$R\&D_{i,t} = \beta_0 + \beta_1 ESG_{i,t} + \beta_2 Size_{i,t} + \beta_3 ROA_{i,t} + \beta_4 CFO_{i,t} + \beta_5 Growth_{i,t} + \beta_6 IOWN_{i,t} + \beta_7 MTB_{i,t} + \beta_8 Age_{i,t} + \sum \gamma_t Year_t + \varepsilon_{i,t}$$

Variable	Coefficient	Std. Error	t-stat	p-value
Constant	1.596	0.401	3.980	0.000
ESG	0.410	0.048	8.380	0.000
Size	-0.029	0.016	-1.800	0.071
ROA	0.106	0.117	-0.910	0.364
CFO	0.007	0.107	0.070	0.946
Growth	-0.110	0.027	-4.100	0.000
IOWN	0.023	0.103	0.230	0.820
MTB	0.0009	0.005	0.180	0.861
Age	-0.344	0.090	-3.800	0.000
Year FE → Controlled				
Chow Test: 7.56, p = 0.0000 → Panel data model accepted				
Hausman Test: 11.86, p = 0.1574 → Random effects model preferred				
Modified Wald Test: 1980.63, p = 0.0000 → Heteroskedasticity present				
Wooldridge Test: 556.967, p = 0.0000 → Serial correlation present				
Pesaran's CD Test: 71.572, p = 0.0000→ Cross-sectional dependence present				

Notes: This table reports random-effects panel regression results. The Chow and Hausman tests support the panel data specification and the use of random effects (p >0.01). Standard errors are robust to heteroskedasticity and serial correlation. Year fixed effects are included to absorb time-specific shocks affecting all firms. The model explains a small part of the within-company variation (R2=0.2619) and the Wald $\chi 2$ statistic indicates overall model significance (Wald $\chi 2$=102.31, p<0.01). No substantial multicollinearity (all VIF < 2) is identified.

Firm size had a negative and marginally significant association with R&D investment (β = -0.029, p = 0.071) among the control variables, indicating that larger firms may experience more organizational rigidity or fewer marginal incentives to increase R&D intensity. Sales growth (β=-0.110) and business age (β= -0.344) are similarly inversely connected to R&D spending, possibly suggesting managerial priority of short-term market performance over long-horizon inventive efforts. The negative coefficient of firm age implies that older firms invest less in R&D, which means organizations become more inflexible as they age and resistant to innovation and long-term risky expenditures. Return on assets, operational cash flows, institutional ownership and business value, however, do not have statistically significant effects, indicating that the decisions on R&D investment are not mainly determined by the current profitability or liquidity situation.

These findings indicate that ESG disclosure functions as an enabling mechanism for sustained innovation, encouraging firms to commit resources to R&D despite uncertainty, long payback periods, and information opacity.

4.3. Results of Hypothesis 2: ESG disclosure is positively associated with firms' access to external financing through debt.

Table 5. Estimation results for Hypothesis 2 (Debt Financing)

$$ExterFLEV_{i,t} = \beta_0 + \beta_1 ESG_{i,t} + \beta_2 Size_{i,t} + \beta_3 ROA_{i,t} + \beta_4 CFO_{it,} + \beta_5 Growth_{i,t} + \beta_6 IOWN_{i,t} + \beta_7 MTB_{i,t} + \beta_8 Age_{i,t} + \sum \gamma_t Year_t + \varepsilon_{it}$$

Variable	Coefficient	Std. Error	t-statistic	p-value
Constant	0.123	0.096	1.280	0.201
ESG	0.977	0.345	2.830	0.005
Size	0.317	0.065	4.880	0.000
ROA	0.239	0.060	3.970	0.000
CFO	-0.526	0.072	-7.220	0.000
Growth	0.180	0.019	9.420	0.000
IOWN	-0.056	0.044	-1.270	0.203
MTB	0.638	0.349	1.830	0.068
Age	-0.013	0.025	-0.530	0.599

Year FE → Controlled
Chow Test: 3.12, p = 0.0000 → Panel data model accepted
Hausman Test: 76.09, p = 0.0000 → Fixed effects model preferred
Modified Wald Test: 449.50, p = 0.0000 → Heteroskedasticity present
Wooldridge Test: 74.734, p = 0.0000 → Serial correlation present
Pesaran's CD Test: 13.111, p = 0.0000→ Cross-sectional dependence present

Notes: This table reports fixed-effects panel regression results. The Chow and Hausman tests support the panel data specification and the use of fixed effects ($p < 0.01$). Standard errors are robust to heteroskedasticity and serial correlation. Time fixed effects control for time-specific shocks affecting all enterprises. The model has a moderate explanatory power ($R2 = 0.2320$) and the Wald $\chi2$ test confirms the overall significance (Wald $\chi2 = 61.26$, $p < 0.01$). All VIFs are below conventional thresholds, indicating no substantial multicollinearity.

Results support Hypothesis 2. ESG disclosure is positively and significantly associated with external debt financing ($\beta = 0.977$, $p < 0.05$), showing that enterprises with better ESG disclosure face fewer challenges to access debt markets. This finding is in line with information asymmetry and signaling theories: it indicates that better ESG disclosure decreases perceived risk and increases creditors' confidence, and so improves firms' borrowing capacity.

Among the control variables, firm size ($\beta = 0.317$), return on assets ($\beta = 0.239$), sales growth ($\beta = 0.180$) and firm value ($\beta = 0.638$, marginally significant) are positively associated with debt financing, consistent with the importance of economic scale, profitability, growth prospects, and market valuation in creditors' lending decisions. In contrast, operating cash flows exhibit a negative and significant effect ($\beta = -0.526$), indicating that firms with stronger internal liquidity rely less on debt financing. Institutional ownership and firm age are not statistically significant.

Overall, the results indicate that ESG disclosure functions not only as a strategic attribute but also as an effective mechanism for facilitating firms' access to external debt financing.

4.4. Results of Hypothesis 3: ESG disclosure is positively associated with firms' access to external financing through equity issuance

The findings provide significant support for Hypothesis 3. ESG disclosure has a positive and statistically significant influence on stock-based external financing ($\beta = 0.856$, $p < 0.01$). This implies that organizations with better ESG disclosure are more effective in raising money through equity issuance.

Among the control variables, firm size ($\beta = 1.230$) and firm value ($\beta = 4.807$) are positively related to equity issuance, which means that larger firms and firms with higher growth potential are more dependent on stock funding. In contrast, profitability (ROA) exhibits a negative and significant effect ($\beta = -0.926$), implying that more profitable firms rely less on equity financing, consistent with the pecking order theory, which suggests that firms prioritize internal financing over external equity

issuance. Other control variables including operating cash, sales, institutional ownership and firm age, do not exhibit statistically significant effects.

The empirical evidence thus indicates that ESG disclosure plays a crucial role in facilitating firms' access to external financing through equity markets.

Table 6. Estimation results for Hypothesis 3 (Equity Financing)

$$ExterFStock_{i,t} = \beta_0 + \beta_1 ESG_{i,t} + \beta_2 Size_{it} + \beta_3 ROA_{it,} + \beta_4 CFO_{i,t} + \beta_5 Growth_{i,t} + \beta_6 IOWN_{i,t} + \beta_7 MTB_{i,t} + \beta_8 Age_{i,t} + \sum \gamma_t Year_t + \varepsilon_{i,t}$$

Variable	Coefficient	Std. Error	t-stat	p-value
Constant	-2.495	0.854	-2.920	0.004
ESG	0.856	0.159	5.350	0.000
Size	1.230	0.410	3.000	0.003
ROA	-0.926	0.382	-2.420	0.016
CFO	-0.096	0.424	-0.230	0.820
Growth	-0.044	0.111	-0.400	0.692
IOWN	-0.391	0.289	-1.350	0.176
MTB	4.807	0.207	2.320	0.021
Age	-0.073	0.183	-0.400	0.690
Year FE → Controlled				
Chow Test: 2.47, p = 0.0000 → Panel data model accepted				
Hausman Test: 11.53, p = 0.1733 → Random effects model preferred				
Modified Wald Test: 1276.33, p = 0.0000 → Heteroskedasticity present				
Wooldridge Test: 70.087, p = 0.0000 → Serial correlation present				
Pesaran's CD Test: 6.031, p = 0.0000 → Cross-sectional dependence present				

Notes: This table reports Random-effects panel regression results. The Hausman test favors the Random-effects specification. Standard errors are robust to heteroskedasticity and serial correlation. Year fixed effects are included to absorb time-specific shocks affecting all firms. The model accounts for a small amount of variation (R2 = 0.2545), but the Wald $\chi 2$ statistic suggests that the model is overall significant (Wald $\chi 2 = 48.70$, $p < 0.01$). No major multicollinearity problem is identified.

Table 7. Estimation results for Hypothesis 4

$$R\&D_{i,t} = \beta_0 + \beta_1 ExterFLEV_{i,t-1} + \beta_2 Size_{i,t} + \beta_3 ROA_{i,t} + \beta_4 CFO_{i,t} + \beta_5 Growth_{i,t} + \beta_6 IOWN_{i,t} + \beta_7 MTB_{i,t} + \beta_8 Age_{i,t} + \sum \gamma_t Year_t + \varepsilon_{i,t}$$

Variable	Coefficient	Std. Error	t-stat	p-value
Constant	0.910	0.298	3.050	0.002
ExterFLEV	0.565	0.046	12.200	0.000
Size	0.030	0.012	2.370	0.018
ROA	-0.021	0.077	-0.280	0.782
CFO	-0.049	0.088	-0.560	0.575
Growth	-0.169	0.049	-3.430	0.001
IOWN	0.315	0.106	2.970	0.003
MTB	-0.015	0.008	-1.880	0.060
Age	-0.152	0.060	-2.530	0.011
Year FE → Controlled				
Chow Test: 7.50, p = 0.0000 → Panel data model accepted				
Hausman Test: 67.88, p = 0.0000 → Fixed effects model preferred				
Modified Wald Test: 7758.08, p = 0.0000 → Heteroskedasticity present				
Wooldridge Test: 486.244, p = 0.0000 → Serial correlation present				
Pesaran's CD Test: 32.681, p = 0.0000→ Cross-sectional dependence present				

Notes: This table reports fixed-effects panel regression results. Standard errors are robust to heteroskedasticity and serial correlation. We include year fixed effects to account for time-specific shocks that affect all companies. The model explains a moderate amount of within-firm variance (R2 = 0.2463) and the Wald $\chi 2$ value indicates overall model significance (Wald $\chi 2 = 176.03$, $p < 0.01$). No major multicollinearity problems are observed.

4.5. Results of Hypothesis 4: External financing through debt is positively associated with firms' R&D investment.

The data support Hypothesis 4. External funding through debt is positively and significantly related to R&D investment (β = 0.565, p < 0.01), demonstrating that the larger the access to debt financing the enterprises have, the bigger the resources they can dedicate to creative activities.

Among the control variables, business size has a positive and significant influence (β = 0.030), indicating that larger firms are more capable of sustaining R&D expenditure. Institutional ownership also has a positive and significant relation (β = 0.315), indicating that increased presence of institutional investors boosts innovation investment. In contrast, R&D has a negative and significant association with sales growth (β = -0.169), which means that fast-growing organizations may focus more on short-term operational expansion than on long-term innovation. Firm age has a negative relationship with R&D investment (β = -0.152), indicating that older enterprises invest less in innovation. Firm value (MTB) is slightly negatively related (β = -0.015), possibly reflecting market pressures for short-term performance. We find no statistically significant effects of profitability (ROA) and operating cash flows (CFO), implying that R&D decisions are driven by financing conditions and strategic considerations, not by contemporaneous financial performance.

Table 8. Estimation results for Hypothesis 5

$$R\&D_{i,t} = \beta_0 + \beta_1 ExterFStock_{i,t-1} + \beta_2 Size_{i,t} + \beta_3 ROA_{i,t} + \beta_4 CFO_{i,t} + \beta_5 Growth_{i,t} + \beta_6 IOWN_{i,t} + \beta_7 MTB_{i,t} + \beta_8 Age_{i,t} + \sum \gamma_t Year_t + \varepsilon_{i,t}$$

Variable	Coefficient	Std. Error	t-stat	p-value
Constant	0.697	0.204	3.400	0.001
ExterFStock	0.519	0.075	6.910	0.000
Size	0.027	0.007	3.520	0.000
ROA	0.036	0.045	0.800	0.421
CFO	0.030	0.057	0.530	0.595
Growth	-0.069	0.032	-2.130	0.033
IOWN	0.065	0.065	1.000	0.320
MTB	-0.012	0.003	-3.050	0.002
Age	-0.083	0.036	-2.280	0.023
Year FE → Controlled				
Chow Test: 6.38, p = 0.0000 → Panel data model accepted				
Hausman Test: 5487.49, p = 0.0000 → Fixed effects model preferred				
Modified Wald Test: 12878.86, p = 0.0000 → Heteroskedasticity present				
Wooldridge Test: 295.966, p = 0.0000 → Serial correlation present				
Pesaran's CD Test: 29.052, p = 0.0000→ Cross-sectional dependence present				

Notes: This table reports fixed-effects panel regression results. Standard errors are robust to heteroskedasticity and serial correlation. Year fixed effects are included to absorb time-specific shocks affecting all firms. The model exhibits moderate explanatory power ($R^2 = 0.2189$), and the Wald χ^2 statistic indicates overall significance (Wald $\chi^2 = 55.37$, $p < 0.01$). No serious multicollinearity concerns are detected.

4.6. Results of Hypothesis 5: External financing through equity issuance is positively associated with firms' R&D investment

The results support Hypothesis 5. External funding through equity issuance has a positive and statistically significant effect on R&D investment (β = 0.519, p < 0.01), indicating that the availability of equity markets encourages more investment in creative projects.

Again, firm size is strongly positively associated with R&D (β = 0.027), showing scale advantages in financing innovation. Similar to the debt-financing model, sales growth (β = -0.069) and company value (β = -0.012) also have negative and significant effects, suggesting a trade-off between short-term market performance and long-term innovation investment. The results show that firm age is inversely related to R&D investment (β = -0.083), suggesting that older firms are less likely to invest in innovation. We also find that other control factors, including profitability, operating cash flows

and institutional ownership, are not significant, consistent with the assumption that R&D expenditure is driven more by availability of external finance than present financial performance.

Table 9. Estimation results for Hypothesis 6

$$R\&D_{i,t} = \beta_0 + \beta_1 ESG_{it} + \beta_2 ExterFLEV_{i,t-1} + \beta_3 Size_{it} + \beta_4 ROA_{it} + \beta_5 CFO_{it} + \beta_6 Growth_{it} + \beta_7 IOWN_{it} + \beta_8 MTB_{it} + \beta_9 Age_{it} + \sum \gamma_t Year_t + \varepsilon_{it}$$

Variable	Coefficient	Std. Error	t-stat	p-value
Constant	0.845	0.268	3.150	0.002
ESG	0.144	0.025	5.760	0.000
ExterFLEV	0.511	0.130	3.930	0.000
Size	0.030	0.007	4.410	0.000
ROA	-0.056	0.046	-1.230	0.219
CFO	0.087	0.061	1.430	0.154
Growth	-0.117	0.038	-3.030	0.002
IOWN	-0.003	0.060	-0.060	0.950
MTB	-0.006	0.003	-1.860	0.063
Age	-0.140	0.054	-2.560	0.010
Year FE → Controlled				
Chow Test: 7.05, p = 0.0000 → Panel data model accepted				
Hausman Test: 34.24, p = 0.0000 → Fixed effects model preferred				
Modified Wald Test: 7784.13, p = 0.0000 → Heteroskedasticity present				
Wooldridge Test: 475.693, p = 0.0000 → Serial correlation present				
Pesaran's CD Test: 23.482, p = 0.0000→ Cross-sectional dependence present				

Notes: This table reports fixed-effects panel regression results. Standard errors are robust to heteroskedasticity and serial correlation. Year fixed effects are included to absorb time-specific shocks affecting all firms. The model explains a moderate proportion of within-firm variation ($R^2 = 0.2676$), and the Wald χ^2 statistic confirms overall model significance (Wald $\chi^2 = 64.00$, $p < 0.01$). No serious multicollinearity is detected.

4.7. Results of Hypothesis 6: External financing through debt mediates the relationship between ESG disclosure and firms' R&D investment

Both ESG disclosure and debt financing are statistically significant and consistent with partial mediation. In particular, ESG disclosure directly and indirectly facilitates R&D investment via debt financing. Among controls, business size has a positive and significant effect on R&D (β=0.030), indicating the importance of organizational ability to enable innovation. Firm age has a negative relationship with R&D investment (β = -0.140), which suggests that older enterprises are less active in investing in innovation. Sales growth is likewise inversely related to R&D (β = -0.117). Other control factors such as ROA, CFO, institutional ownership, and firm value (p = 0.063) are not statistically significant at the conventional level, indicating the predominant effect of ESG and the finance channel on R&D spending.

4.8. Results of Hypothesis 7: External financing through equity issuance mediates the relationship between ESG disclosure and firms' R&D investment

Both ESG disclosure and equity financing are statistically significant and consistent with partial mediation. ESG disclosure, directly and indirectly, improves R&D investment through equity financing.

Among control factors, business size is positively and strongly associated with R&D (β = 0.034), indicating scale advantages in innovation finance. R&D (β = -0.068) is adversely associated with sales growth, which may reflect a trade-off between short-term growth and long-term innovation. The firm valuation (MTB) is adversely related to R&D (β = -0.010), indicating market pressure for short-term performance. The negative relationship between business age and R&D spending (β = -0.115) suggests that older firms are less likely to invest in innovation. Other control variables such as ROA, CFO and institutional ownership are not statistically significant, which further emphasizes the pivotal

importance of ESG and external financing as the drivers of innovation investment.

To ensure the robustness of the main findings, additional diagnostic tests (Sobel tests and logit models) are conducted for the mediating role of external financing—encompassing both debt and equity—as presented in Tables 11 and 12.

Table 10. Estimation results for Hypothesis 7

$$R\&D_{i,t} = \beta_0 + \beta_1 ESG_{it} + \beta_2 ExterFStock_{i,t-1} + \beta_3 Size_{it} + \beta_4 ROA_{it} + \beta_5 CFO_{it} + \beta_6 Growth_{it} + \beta_7 IOWN_{it} + \beta_8 MTB_{it} + \beta_9 Age_{it} + \sum \gamma_t Year_t + \varepsilon_{it}$$

Variable	Coefficient	Std. Error	t-stat	p-value
Constant	0.801	0.219	3.650	0.000
ESG	0.107	0.021	5.110	0.000
ExterFStock	0.518	0.074	6.950	0.000
Size	0.034	0.008	4.120	0.000
ROA	0.020	0.044	0.460	0.647
CFO	0.018	0.059	0.310	0.755
Growth	-0.068	0.032	-2.140	0.032
IOWN	0.019	0.064	0.300	0.762
MTB	-0.010	0.003	-2.800	0.005
Age	-0.115	0.042	-2.750	0.006

Year FE → Controlled
Chow Test: 5.88, p = 0.0000 → Panel data model accepted
Hausman Test: 253.76, p = 0.0000 → Fixed effects model preferred
Modified Wald Test: 12700.69, p = 0.0000 → Heteroskedasticity present
Wooldridge Test: 282.608, p = 0.0000 → Serial correlation present
Pesaran's CD Test: 26.730, p = 0.0000→ Cross-sectional dependence present

Notes: This table reports fixed-effects panel regression results. Standard errors are robust to heteroskedasticity and serial correlation. Year fixed effects are included to absorb time-specific shocks affecting all firms. The model explains a moderate level of within-firm variance (R2 = 0.2659). The Wald $\chi 2$ statistic shows the overall importance of the model (Wald $\chi 2 = 74.02$, $p < 0.01$). No substantial multicollinearity is found.

Table 11. Robustness test results for hypotheses 6 & 7 (Sobel tests)

Hypothesis	Test type	Test statistics	Sig.	Result
H6	Sobel test	2.756	0.005	Mediating Role Confirmation
	Aroian test	2.748	0.005	
	Goodman	2.765	0.005	
H7	Sobel test	4.230	0.000	Mediating Role Confirmation
	Aroian test	4.202	0.000	
	Goodman	4.258	0.000	

Given that the Sobel test statistic for the indirect effect equals 2.756 and 4.230, with corresponding significance levels below 5% (0.005 and 0.000), the sixth and seventh hypotheses of the study are accepted. This implies that the mediating effect of external financing (through debt and equity) on the relationship between ESG and R&D is positive and significant. Furthermore, the results of the other tests, despite significance levels below 5%, indicate the existence of a positive relationship among these variables. The Sobel test was performed based on fixed-effects estimations.

Finally, the robustness tests using logit estimation fully confirm the main model results. All hypotheses (H1, H4, H5, H6, H7) are supported. The prediction accuracy of the models is between 72.43% and 79.54%. The Hosmer-Lemeshow goodness-of-fit tests suggest no indication of model misspecification (all p-values > 0.05). The best predictive performance is found for H6 (debt mediation), revealing the importance of the indirect effects of ESG via debt financing on R&D investment. Overall, these results indicate that the primary empirical findings are robust to alternative model specifications and are not a product of functional form assumptions.

Table 12. Robustness test results for hypotheses (Logit Model)

Hyp..	Test Name	Test Statistic	Result
H1	Percentage of Correct Predictions (PCP)	%77.04	Acceptable predictive accuracy
	Hosmer-Lemeshow	$\chi^2 = 3.92$ ($p = 0.8645$)	The model shows a good fit
H4	Percentage of Correct Predictions (PCP)	%72.43	Acceptable predictive accuracy
	Hosmer-Lemeshow	$\chi^2 = 6.55$ ($p = 0.5864$)	The model shows a good fit
H5	Percentage of Correct Predictions (PCP)	%78.82	Acceptable predictive accuracy
	Hosmer-Lemeshow	$\chi^2 = 8.69$ ($p = 0.3693$)	The model shows a good fit
H6	Percentage of Correct Predictions (PCP)	%79.54	Acceptable predictive accuracy
	Hosmer-Lemeshow	$\chi^2 = 12.69$ ($p = 0.1231$)	The model shows a good fit
H7	Percentage of Correct Predictions (PCP)	%77.17	Acceptable predictive accuracy
	Hosmer-Lemeshow	$\chi^2 = 12.99$ ($p = 0.1123$)	The model shows a good fit

5. Discussion

This study examined the relationship between ESG disclosure and corporate R&D investment, with particular emphasis on the mediating role of external financing. The empirical analysis was conducted on a sample of 152 companies listed on the Tehran Stock Exchange throughout 2015-2024. The study offers an integrated perspective on how corporate sustainability-related practices are tied to firms' innovation financing decisions by jointly examining ESG disclosures, external financing channels, and R&D spending.

Results for Hypothesis 1 demonstrate a positive and statistically significant link between ESG disclosure and R&D investment. The firms with more comprehensive ESG disclosure tend to spend more resources on research and innovation activities. This outcome is compatible with stakeholder theory and the information asymmetry view within the theoretical framework. Good ESG disclosure policies help build stakeholder trust and boost corporate reputation. Good governance frameworks increase transparency and improve internal resource allocation. These elements combine to generate an organizational environment supportive of long-term investment in innovation. Moreover, increased ESG disclosure could also be indicative of higher managerial quality and a long-term strategic perspective, along with a prolonged R&D effort.

The results are also consistent with signaling theory. ESG disclosure can serve as a credible signal of firm quality and risk management capability, reducing perceived uncertainty associated with high-risk and intangible investments such as R&D. In this context, ESG disclosure is not merely a response to ethical or regulatory pressures but is associated with firms' strategic investment behavior. These results are consistent with previous empirical studies (e.g., Lee, 2025; Chen et al., 2026; Rauf et al., 2024) and imply that increasing ESG disclosure could help firms' innovation ability by providing a longer investment horizon and boosting stakeholder confidence. Interestingly, profitability (ROA) and operating cash flow (CFO) do not have a significant influence on R&D spending. This result implies that R&D investment is more a long-run strategic decision rather than a short-run profitability or liquidity-driven decision. Instead, organizations seem to rely more on their external finance capability and enhanced information transparency, as indicated by higher ESG disclosure, to sustain innovation investment.

The results for Hypothesis 2 show that ESG disclosure is positively associated with external finance through debt. Firms with better ESG disclosure have more access to debt funding. Thus, lenders see ESG participation as a signal of lower credit risk, better governance and higher transparency. From a financial standpoint, better ESG disclosure can minimize knowledge asymmetry

and perceived default risk, which could lead to creditors' readiness to give finance on more favorable terms. This finding is in line with previous studies on the impact of ESG on loan decisions and cost of debt (e.g., Srivastava et al., 2022; Rong and Kim, 2024).

Strategically, these results imply that ESG initiatives can function as a financial asset by improving firms' borrowing capacity, rather than merely serving reputational or compliance objectives.

Similarly, the results for Hypothesis 3 show that ESG disclosure is positively and significantly associated with equity-based external financing. Firms with higher ESG disclosure have an advantage in raising equity issuance capital. This association could be explained by the lower operational, regulatory and reputational risks associated with high standards of ESG disclosure and the higher quality of corporate transparency and governance. These qualities boost investor trust and lessen concerns about opportunistic conduct or information asymmetry. According to signaling theory, ESG disclosure appears to communicate positive information to capital markets, particularly to investors with long-term or sustainability-oriented investment objectives. Our findings are consistent with recent research that documents the impact of ESG in facilitating equity financing and reducing the cost of equity capital (e.g., Zhao and Zhang, 2024). Together with the debt-financing results, these findings imply that financial markets appreciate nonfinancial transparency more than traditional measures of accounting. Creditors seem to react mainly to ESG disclosure as a signal of decreased default risk and better risk management, while equity investors seem to favor its implications for long-term growth outlooks and sustainable value creation.

The results of Hypothesis 4 show that the link between external debt financing and R&D spending is positive and significant. Firms with better access to debt finance are more likely to spend on research and innovation. Debt financing can ease financial constraints as well as enable corporations to execute long-term projects beyond domestically produced cash to facilitate R&D investment. Furthermore, debt could be an appealing source of funding for innovation due to the tax advantages of debt and the often lower cost of capital of debt compared to equity, provided that leverage is maintained at reasonable levels. This result is in line with the trade-off theory that stresses the trade-off between the advantages and costs of leverage. If handled judiciously, debt can be a useful tool for supporting innovation while protecting shareholder value. These results are in line with previous investigations (e.g., Su et al., 2021).

The results for Hypothesis 5 reveal that equity-based external finance is likewise favorably associated with R&D investment. Financial resources from equity issuance can be utilized for funding research and development (R\&D) projects, which often have long payback times and considerable unpredictability. Equity financing reduces liquidity strain and financial risk because it does not have fixed repayment commitments like debt financing. This flexibility helps corporations to sustain R&D spending for long periods of time without growing leverage. Equity funding plays a significant role in supporting innovation, particularly for companies that pursue growth-oriented or technology-intensive strategies. These findings are consistent with previous evidence that equity markets promote innovation by providing patient funding for risky long-term investments (e.g., Moon, 2022; Müller and Zimmermann, 2009).

These findings together imply that external funding is not just a substitute source of capital but rather a vital enabler of ongoing innovation investment. Since R&D activities are long-term, uncertain and resource-intensive, organizations with more funding flexibility are better able to maintain their innovation initiatives despite short-term volatility in internal cash flows.

The results of Hypothesis 6 imply that debt-based external financing somewhat mediates the relationship between ESG disclosure and R&D spending. The positive association between ESG disclosure and R&D investment exists even when adjusting for debt financing. Debt financing is strongly positively related to R&D. This pattern shows that ESG disclosure influences R&D spending

both directly and indirectly through better access to the loan markets of corporations. Companies with excellent ESG disclosure are seen as less risky and more transparent, which helps with borrowing and allows for more investment in innovation. Thus, debt financing is an essential transmission mechanism linking ESG disclosure to firms' innovation activities, consistent with recent empirical findings (e.g., Yao et al., 2022; Liu et al., 2025).

Similarly, the results for Hypothesis 7 show that equity-based external financing somewhat mediates the association between ESG disclosure and R&D spending. ESG disclosure and equity financing both have a favorable and significant connection with R&D expenditure. This study shows that ESG disclosure improves the attractiveness of enterprises to equity investors, which in turn facilitates capital raising and helps in investment in innovation. ESG disclosure facilitates the access to equity financing and helps enterprises to grow R&D activities without raising financial risk, therefore promoting long-term innovation capability. These results are in line with previous studies showing that ESG disclosure matters in alleviating equity financing frictions and fostering innovation-led growth (e.g., Chen et al., 2026; Liu et al., 2025).

The partial mediation results further show that external financing is not the only mechanism via which ESG disclosure influences R&D spending. Other reasons, such as more robust stakeholder relationships, improved business reputation, better governance quality, and more managerial commitment to long-term value creation, may also help explain the direct positive relation between ESG disclosure and innovation investment.

Together, the results suggest that ESG disclosure is closely associated with firms' innovation investment, both directly and through its influence on external financing channels. Debt and equity financing appear to function as complementary channels through which ESG disclosure is associated with higher R&D investment. The findings from the managerial perspective suggest that ESG disclosure has the potential to generate financial and strategic benefits in addition to compliance and reputation management. The results are consistent with the claim that firms with higher ESG disclosure may have easier access to external finance, which, in turn, might facilitate long-term investment in innovation and increase firms' competitive stance. The findings underscore the potential significance of ESG-related disclosures and standards for policymakers and regulators to improve the efficiency of capital markets and encourage sustainable innovation, especially in emerging nations. More generally, these results imply that the importance of ESG disclosure is not only ethical or regulatory. By improving information quality and reducing financing frictions, ESG disclosure can become an integral component of firms' long-term financial strategy for supporting innovation. This mechanism may be particularly important in emerging markets, where information asymmetry and financing constraints are generally more pronounced.

6. Conclusion and implications

The study examined the association between ESG disclosure and corporate R&D spending, with a special emphasis on the mediating function of external financing. The results obtained from the panel data of the firms listed on the Tehran Stock Exchange show that the relationship between ESG disclosure and R&D investment is positive both directly and indirectly through improved access to debt and equity finance. Overall, the results indicated that ESG disclosure has a positive association with firms' innovation activity, and external finance may be an essential channel of this association.

From a management perspective, the results suggested that enhancements in ESG disclosure can facilitate long-term innovation by improving firms' credibility and access to external financing. Managers right therefore think of ESG disclosure as part of an integrated strategy that ties sustainability reporting to innovation finance. The findings stressed the relevance of financial analysts and investors considering ESG disclosure in addition to conventional financial indicators when

determining a firm's innovation potential and ability to obtain finance.

From a policy perspective, the evidence pointed to potential upside in developing better ESG disclosure norms and procedures. Increased transparency and auditability of ESG information can improve the confidence of creditors and investors, hence facilitating access to external finance for companies and boosting innovation-led growth.

The study also has limitations. This study analyzes the extent of ESG disclosure, but does not directly distinguish substantive from symbolic disclosures. Thus, the results should be regarded as evidence for the general relation between ESG disclosure, external funding and R&D expenditure and not the effectiveness of different types of disclosure. Future studies might further examine whether these correlations vary as a function of the trustworthiness, quality, or content of ESG disclosures. Future research could extend this study by incorporating additional mediating or moderating variables such as financial distress or managerial traits, and by exploring heterogeneity at the industry level and different periods of the company life cycle. Further research might also include macroeconomic circumstances such as inflation, currency rate volatility, and economic penalties, to better reflect the wider environment in which ESG, finance and innovation decisions are made.

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