



SCHOOL OF
ECONOMICS AND
MANAGEMENT

BUSN79 - Degree Project in Accounting and Finance

Spring 2024

Thesis Group: 27

24 May 2024

How do ESG ratings influence the cost of equity and debt for companies in the biotechnology sector, and how does this impact vary across the United States, Germany, and China?

Authors:

Shunshun Qiu

Chenyu Zheng

Supervisor: Zahida Sarwary

Examiner: Diem Nguyen

Abstract

Title: How do ESG Ratings Influence the Cost of Equity and Debt for Companies in the Biotechnology Sector, and How Does This Impact Vary Across the United States, Germany, and China?

Seminar date: 31 May 2024

Course: BUSN79 - Degree Project in Accounting and Finance

Authors: Shunshun Qiu & Chenyu Zheng

Advisor: Zahida Sarwary

Keywords: ESG, Cost of Equity, Cost of Debt, Biotechnology, United States, Germany, China

Purpose: This study investigates the impact of Environmental, Social, and Governance (ESG) ratings on the cost of equity and debt for biotechnology companies across the United States, Germany, and China. It aims to determine whether higher ESG scores correlate with lower financing costs and how these impacts vary across different national contexts, contributing to the literature on sustainable finance in the biotechnology sector.

Methodology: The study employs fixed-effects regression models to analyze a dataset comprising firm-year observations from publicly listed biotechnology companies in the United States, Germany, and China between 2013 and 2023 (the past ten years) as the research sample.

Theoretical Perspectives: The analysis is grounded in several financial theories, including agency theory, information asymmetry theory, stakeholder theory, legitimacy theory, and signaling theory.

Empirical Foundation: The dataset consists of 4410 observations, forming panel data. The data analysis was conducted using Stata 17.0.

Conclusions: ESG ratings play a critical role in lowering financing costs for biotechnology companies, with varying impacts influenced by national policies, market maturity, and investor preferences. The findings underscore the importance of integrating ESG practices into corporate strategies to enhance financial performance and sustainability.

Contribution: This study provides empirical evidence that higher ESG performance can lower the cost of capital, offering a theoretical basis and practical motivation for biotechnology companies to enhance their ESG practices. It also informs investors and policymakers about the financial benefits of sustainability, promoting comprehensive development and rapid growth of the ESG system.

Contents

1. Introduction.....	1
1.1 Background	1
1.2 Problem Statement.....	3
1.3 Purpose and Research questions.....	4
1.4 Main Findings	4
1.5 Contribution	5
1.6 Limitations	5
2. Literature Review.....	6
2.1 The concept of ESG.....	6
2.2 The Concept of Costs of Capital	7
2.3 Overview of the Biotechnology Sector in Each Country	8
2.4 Existing Research	12
2.5 Theoretical Framework.....	13
2.5.1 Information Asymmetry Theory	13
2.5.2 Signaling Theory.....	15
2.5.3 Agency Theory.....	15
2.5.4 Stakeholder Theory	16
2.6 Hypotheses Development	19
3. Methodology.....	21
3.1 Data Sources and Sample Selection	21
3.2 Variable Definition	22
3.2.1 Dependent Variable	22
3.2.2 Independent Variable.....	22
3.3 Model Selection.....	25
3.4 Regression Model.....	25
3.4.1 Basic Regression Model	25
3.4.2 Country-Specific Regression Models	26

4. Empirical Analysis	26
4.1 Descriptive Analysis	26
4.2 Correlation Analysis	29
4.3 Overall Sample Regression	31
4.4 Country-Specific Regressions	33
4.4.1 China	33
4.4.2 Germany	33
4.4.3 United States of America.....	34
4.4.4 Analysis of Differences Between Countries.....	34
4.5 Robustness Checks	37
4.5.1 Heterogeneity Test	37
4.5.2 Endogeneity and Hausman Test.....	38
5. Conclusion	38
Reference	40

1. Introduction

1.1 Background

In recent years, issues such as climate change, pandemics, population aging, and resource shortages have become increasingly prominent, posing more challenges and uncertainties for countries and companies worldwide, from macro to meso levels. Against this backdrop, the concept of Environmental, Social, and Governance (ESG) has gained significant recognition as a mainstream evaluation system for the non-financial performance of companies globally. ESG has become a core framework and systematic methodology for promoting sustainable corporate development.

The biotechnology industry plays a critical role in addressing global challenges such as health crises and environmental sustainability, and it is highly dependent on external financing, especially for research and development funds. Activities in this industry involve ethical and environmental considerations, making ESG performance particularly important. As ESG factors increasingly influence investor decisions and regulatory frameworks, understanding how ESG ratings affect the cost of equity and the cost of debt in the biotechnology sector in the United States, Germany, and China has become essential.

Globally, the concept of ESG is increasingly influencing investor decisions. According to the United Nations Principles for Responsible Investment (UNPRI), the total assets under management by global signatories have exceeded \$100 trillion, reflecting the market's high focus on ESG investing. Additionally, research indicates that companies with strong ESG performance often enjoy lower financing costs. This is because high ESG ratings can reduce a company's risk premium, making it more attractive in the capital markets. However, the emphasis and specific impact of ESG vary across different markets.

In the United States, ESG investing has gradually become mainstream. The U.S. Securities and Exchange Commission (SEC) has also been enhancing its requirements for ESG disclosure by publicly traded companies. Studies show that in the U.S. market, companies with strong ESG performance typically enjoy lower costs of equity and debt. However, the specific impact of different types of ESG factors (environmental, social, governance) on financing costs may vary. For example, environmental factors might have a greater impact on energy-intensive companies, while social and governance factors could be more significant for biotechnology companies.

In Germany, ESG principles are also highly valued. Both the German government and EU institutions are promoting stronger ESG disclosure and practices among companies. German companies excel in environmental and social responsibility, which not only boosts their international competitiveness but also lowers their financing costs to some extent. Particularly in the biotechnology industry, corporate social responsibility and governance structures significantly influence investor decisions. In Germany, the ESG legal framework and regulatory system are primarily led by the EU. For instance, the Corporate Sustainability Reporting Directive (CSRD) requires companies to provide detailed reports on their ESG performance. This directive applies not only to Germany but also to other EU member states, aiming to enhance corporate transparency and sustainability. The Federal Financial Supervisory Authority (BaFin) in Germany also emphasizes the importance of sustainable finance and plans to make it a regulatory priority (ICLG, 2024).

In China, driven by national policies, the concept of ESG is gradually being embraced by companies and investors. In 2021, the China Securities Regulatory Commission (CSRC) issued the "Guidelines for Investor Relations Management of Listed Companies (Draft for Comments)," requiring listed companies to proactively communicate their ESG-related information to investors. As a key industry with significant impacts on the national economy and public health, the biotechnology sector's ESG disclosure is particularly crucial. By

strengthening ESG practices, companies can not only improve their sustainability but also enhance their social responsibility awareness, ultimately achieving long-term development and value. As a signatory of the Paris Agreement, China is committed to fulfilling its international obligations and announced goals to peak carbon emissions by 2030 and achieve carbon neutrality by 2060. This strategy is not only an intrinsic requirement for promoting high-quality economic development but also a responsibility for building a community with a shared future for humanity.

1.2 Problem Statement

The biotechnology sector plays a crucial role in addressing global challenges such as health crises and environmental sustainability. This industry heavily relies on external financing to fund its extensive research and development activities. In recent years, Environmental, Social, and Governance (ESG) ratings have gained prominence as indicators of a company's ethical standards and sustainable development practices. Investors and regulatory bodies are increasingly considering ESG ratings in their financial decision-making processes. However, the impact of ESG ratings on the cost of equity and debt for biotechnology companies has not been thoroughly explored, especially across different regulatory and cultural environments.

This study aims to investigate how ESG ratings affect the cost of equity and debt for biotechnology companies within different regulatory and cultural contexts. The United States, Germany, and China represent distinct markets, each embodying its continent, with varying regulatory frameworks and investor expectations. These differences may lead to diverse impacts of ESG ratings on financing costs. In the market-driven United States, ESG factors might significantly influence investor behavior and corporate financing. In contrast, Germany's proactive government policies and financial support for biotechnology could result in different dynamics. China's rapidly evolving regulatory environment, with an emphasis on sustainable development, provides another unique perspective on the relationship between ESG factors and financing.

By conducting a comparative analysis, this study will fill a gap in the existing literature and offer new insights into the relationship between ESG ratings and financing costs. Such research can provide biotechnology companies with recommendations for improving ESG management and offer investors more comprehensive decision-making information, contributing to the sustainable development and value growth of the global biotechnology industry.

1.3 Purpose and Research questions

Our study aims to provide empirical evidence to deepen the understanding of the relationship between Environmental, Social, and Governance (ESG) factors and financing, particularly in the biotechnology industry, which is crucial for addressing global health and environmental challenges. Our paper seeks to explore the following questions:

Research Question 1: Do ESG ratings influence the cost of equity and debt for companies in the biotechnology sector?

Research Question 2: How does the impact of ESG ratings on the cost of equity differ between biotechnology companies in the United States, Germany, and China?

1.4 Main Findings

We find that ESG ratings significantly reduce the cost of equity and debt for biotechnology companies. Specifically, ESG ratings decrease the cost of equity by 0.009% and the cost of debt by 0.206%. The impact varies across countries: in Germany, ESG ratings have the greatest effect on reducing equity costs by 0.019%, due to stringent regulations and mature markets. In China, ESG ratings notably reduce debt costs by 0.304%, driven by government policies promoting green finance. In the United States, ESG ratings reduce equity costs by 0.012% and debt costs by 0.218%, with a relatively smaller impact due to the market-driven nature of its capital markets. These findings highlight the importance of ESG ratings in lowering financing costs, with varying degrees of impact influenced by national policies, market maturity, and

investor preferences.

1.5 Contribution

Our study reveals how ESG performance impacts the cost of equity and debt for biotechnology companies, providing a strong theoretical basis and motivation for companies to enhance their ESG practices. By taking greater responsibility in environmental, social, and governance areas, companies can align with government policies and gain more development opportunities, creating a win-win situation. Additionally, this research raises awareness among stakeholders about the importance of ESG investment principles. It encourages investors to consider ESG ratings when making investment decisions and to assess a company's future prospects and profitability alongside national policies. With companies adhering to ESG standards and investors valuing these principles, both can work together to promote the comprehensive development and rapid growth of the ESG system.

1.6 Limitations

Despite using a fixed-effects model in this study to control for firm-specific effects, not all potential endogeneity issues have been fully addressed. Future research should consider employing instrumental variable methods or other techniques to mitigate endogeneity and improve the accuracy of the estimates. For example, identifying suitable instrumental variables or using natural experiments could provide more precise parameter estimates. This would help validate the findings of this study and offer more reliable evidence for policy-making.

Another limitation lies in the availability and quality of data across different countries and firms, which might affect the consistency and accuracy of the analysis. Although the study focuses on the major markets of the United States, Germany, and China, it does not include other potentially relevant markets or regions. This means the findings might not be generalizable to biotechnology companies operating in different regulatory and cultural environments.

Additionally, the influence of external factors such as the COVID-19 pandemic could impact

the results. The pandemic has affected global markets and could influence ESG practices and reporting, thus potentially affecting financing costs.

Lastly, the database used in this study mainly includes companies with available ESG ratings, potentially leading to a selection bias. Companies with more robust ESG practices are more likely to disclose their ESG ratings, which might not represent the broader population of biotechnology firms. Future research should aim to include a more diverse set of firms and consider the potential impact of non-disclosure on the results.

2. Literature Review

2.1 The concept of ESG

The concept of ESG was first introduced by the United Nations in 2004. ESG stands for Environmental, Social, and Governance, representing a company's proactive actions in environmental protection and pollution control, its social responsibilities during development, and its level of corporate governance. ESG evaluates a company's sustainability and impact on social values from three dimensions: environment, social, and governance. It covers a broader scope of stakeholder responsibilities and provides more extensive information. In the environmental section, companies report on pollution control, consumption of raw materials and energy, and other contributions related to sustainable development. On the social side, disclosures include labor relations, employee welfare, and initiatives to promote community development. As a report on non-financial information, ESG performance demonstrates a company's commitment to sustainable development and long-term value, effectively reducing information asymmetry to some extent. It enhances the supervision of accounting information quality and provides external stakeholders with valuable information beyond financial reports, thereby improving the quality of corporate information.

In recent years, Environmental, Social, and Governance (ESG) standards have become an

essential part of global corporate strategy, marking a significant shift towards sustainable development and ethical practices in the business world. ESG ratings assess a company's commitment to social and environmental factors, playing a crucial role in aligning business operations with broader societal goals such as environmental sustainability, social responsibility, and ethical governance. The focus on sustainability in business and investment decisions has evolved from ethical and philanthropic motives to mainstream market goals aimed at achieving superior financial performance (Fulton et al., 2012).

2.2 The Concept of Costs of Capital

The cost of capital is the minimum return a company must earn before it can create value. Before making a profit, a company needs to generate enough revenue to cover its capital costs. The company's cost of capital largely depends on its financing structure. Typically, a company's financing methods are divided into two categories: debt financing and equity financing. Depending on its development characteristics and needs, a company can choose a financing structure that promotes growth and reduces operational risks. It can rely solely on equity or debt financing or use a combination of both. Accordingly, the cost of financing can be divided into the cost of equity and the cost of debt.

Equity financing involves raising capital by giving up some control of the company to external investors. This includes private equity and public offerings. The cost of equity is the return rate that the company must pay to equity investors.

Since equity investors demand a higher risk premium than creditors, the cost of equity is typically higher. However, equity financing has its advantages: the funds raised do not require repayment of the principal or payment of fixed interest, eliminating the risk of financial distress due to inability to meet debt obligations. Additionally, equity financing can help form a reasonable governance structure, standardize operations, and enhance the company's long-term profitability. When raising large amounts of capital, equity financing can be simpler. However,

it can also dilute existing shareholders' control over the company, which might not always be desirable.

Debt financing typically includes borrowing from financial institutions (such as bank loans and finance leases) and issuing bonds in the capital market (such as corporate bonds and convertible bonds). The cost of debt is the expense incurred by the company to raise funds through these methods, including transaction fees and interest payments. Compared to equity, debt is a cheaper source of financing. Companies benefit from debt financing by paying interest on existing debt, which reduces taxable income. The tax shield effect of debt financing is crucial as it helps maintain cash flow and overall company value. Furthermore, if the return on assets exceeds the cost of debt financing, debt can enhance the return on equity and increase the financial leverage effect.

However, for highly leveraged companies, adding new debt can increase default risk, meaning the inability to meet interest and principal payments. Higher default risk increases the cost of debt as new creditors demand higher risk premiums. Moreover, high default risk can also increase the cost of equity, as shareholders demand higher risk premiums than creditors due to additional risks.

2.3 Overview of the Biotechnology Sector in Each Country

In the ever-evolving landscape of the U.S. biotechnology sector, the post-pandemic era has presented a complex array of challenges and opportunities. Initially surging due to the demand for COVID-19 vaccines and therapeutics, the market has now begun to normalize. However, the industry faces significant upheaval due to the impending expiration of patents on key biologic drugs. This scenario threatens established revenue streams while opening the market to generics and biosimilars manufacturers (Ernst & Young Global Limited, 2023, para. 4).

Regulatory influences are markedly shaping the sector's trajectory. Recent stringent actions by

the U.S. Federal Trade Commission (FTC) against mergers and acquisitions are poised to restrict the scalability of new therapies. Moreover, the Inflation Reduction Act (IRA) introduces new pricing regulations that could compress margins, impacting the profitability and financial strategies of biotech firms. These regulatory frameworks aim to enhance healthcare affordability but present considerable challenges to the financial viability and strategic planning within the sector.

Financially, the U.S. biotechnology sector relies significantly on external funding through venture capital, IPOs, and subsequent public offerings. The economic downturn, coupled with rising interest rates and inflation, has starkly curtailed the availability of capital, compelling biotech companies to adopt more strategic and prudent financial planning to navigate these tighter conditions.

Environmental, Social, and Governance (ESG) considerations are increasingly integral to the sector's operations. Biotech companies are integrating sustainable operational practices and improving governance structures to meet growing investor and societal demands. The social component, emphasizing patient advocacy and broader access to medicine, highlights the sector's commitment to societal impact beyond financial metrics. The integration of ESG factors is crucial for risk mitigation and enhancing the long-term value and reputation of companies within the industry (Ernst & Young Global Limited, 2023, para. 4).

This overview reflects a sector at a critical juncture, where adaptation to regulatory changes, financial constraints, and increasing ESG expectations will likely determine the future success and stability of biotech firms in the U.S. The sector's ability to navigate these complex dynamics will be paramount in maintaining its trajectory of innovation and growth in the challenging economic landscape ahead (Beyond Borders: EY Biotechnology Report 2023).

In contrast, Germany's biotechnology sector has been shaped by early government

interventions aimed at fostering growth through extensive funding and supportive policies. This approach contrasts with the U.S. strategy, which has relied more on market mechanisms and indirect support through regulatory frameworks (Giesecke, 2000). Despite Germany's proactive stance, the U.S. biotechnology sector outpaced its German counterpart in terms of innovation and market dynamics, attributed to the U.S.'s more flexible and conducive "economic ecology" for biotech development (Giesecke, 2000).

In the evolving landscape of sustainable finance, the integration of ESG considerations into financial strategies is increasingly shaping investment decisions and product development. The European Union (EU) has been at the forefront of regulatory innovations, with the EU Taxonomy Regulation establishing a classification system for environmentally sustainable activities. This system guides investment by defining criteria that economic activities must meet to be considered sustainable, significantly influencing capital flows towards greener investments (ICLG, 2024).

Complementing the EU Taxonomy, the Corporate Sustainability Reporting Directive (CSRD) mandates comprehensive ESG disclosures, enhancing transparency and accountability. Starting in 2024, this directive requires companies to provide detailed sustainability information, facilitating informed decision-making by investors (ICLG, 2024). These regulatory frameworks are pivotal in transitioning financial markets towards sustainability, underpinning the EU's commitment to achieving its climate and environmental goals.

Financial products like the EU Climate Transition and Paris-Aligned Benchmarks reflect this regulatory push, offering investors tools to identify investments that align with the decarbonization trajectory and the objectives of the Paris Agreement. Such benchmarks are essential for directing finance towards sustainable economic activities and combating greenwashing by ensuring the credibility and comparability of green claims (ICLG, 2024).

Overall, these developments underscore a significant shift in financial markets, where sustainability factors are deeply integrated into financial governance and investment strategies, setting a benchmark for global financial practices (ICLG, 2024).

In recent years, issues such as climate change, pandemics, population aging, and resource shortages have become increasingly prominent. These challenges bring greater uncertainty and complexity both at the macro level for countries and at the meso level for companies. To address climate change, China has set strategic goals of "carbon peaking" and "carbon neutrality," aiming to peak carbon emissions by 2030 and achieve carbon neutrality by 2060.

The Chinese government is also committed to improving ESG-related policies that align with the national capital market. In February 2021, the China Securities Regulatory Commission (CSRC) issued the "Guidelines for Investor Relations Management of Listed Companies (Draft for Comments)," which included ESG requirements for companies to proactively communicate ESG-related information to investors. In June 2021, the Hong Kong Securities and Futures Commission released the latest ESG fund disclosure requirements, mandating that ESG funds disclose regular assessments of their consideration of ESG factors and content. Environmental responsibility has gradually become an important guarantee for the sustainable development of enterprises. Companies are expected to create economic profits while also taking responsibility for the ecological environment.

As China has not formally established a mandatory environmental disclosure system, considerable differences exist in the environmental disclosures of A-share listed companies, and the disclosure situation is relatively singular (Shen Hongbo et al., 2022). Compared to other industries, the biotechnology sector needs to pay more attention to and respond to the expectations and demands of stakeholders. However, the ESG concept is relatively new to Chinese biotechnology companies, and the effectiveness of ESG practices is generally not ideal. Nevertheless, Chinese companies face urgent needs to enhance competitiveness, expand into

overseas markets, and alleviate financing constraints. Therefore, they must engage in ESG practices to adapt to rating agencies' assessments and respond to stakeholder demands.

For companies, choosing to actively engage in ESG management practices not only responds to stakeholder demands but also sets higher standards for themselves, indicating a desire to find sustainable development paths and intrinsic motivation. Thus, proactive ESG practices are an inevitable choice for the future development of Chinese biotechnology companies.

2.4 Existing Research

Currently, many scholars conduct empirical studies to explore the impact of ESG reporting on a company's performance in the capital market. By intuitively using stock prices, they demonstrate the correlation between ESG and corporate value, finding that ESG ratings are positively related to corporate value. LiY et al. (2017) found that corporate value can be enhanced through improved ESG information disclosure. Ziegler et al. (2011) discovered that companies with higher levels of ESG disclosure perform better in the capital markets in Europe and the United States. Additionally, Krishnamurti and Velayutham (2018) argued that high-quality carbon information disclosure can stabilize stock prices. FlammerC (2015) suggested that ESG practices help companies gain stakeholder recognition, reduce consumer price sensitivity, and build brand effects, thereby enhancing competitiveness and creating value for the company.

The mutual influence between ESG performance and corporate financial activities is further reflected in the comprehensive impact on corporate capital costs. Many scholars have found that engaging in ESG practices can lower the weighted average cost of capital (WACC). Empirical research shows that higher ESG scores are negatively correlated with WACC, and companies with good environmental performance have lower costs of equity and debt capital. Rezaee (2021) provided evidence that better ESG performance results in lower equity capital

costs. Atan et al. (2018) analyzed data from 54 companies and pointed out that, while individual ESG components (environmental, social, governance) might not significantly correlate with corporate financial performance, the overall ESG score positively relates to lower capital costs.

Although prioritizing environmental, social, and governance performance is intuitively considered beneficial for companies, some literature presents opposing results, suggesting that investing in ESG might be detrimental to manufacturers. Studies supporting this view indicate that ESG performance either does not affect financial performance or negatively impacts it (Becchetti & Ciciretti, 2009; Boyle et al., 1997). Furthermore, according to the Environmental Kuznets Curve (EKC), the burden on environmental resources increases with industrial development until it surpasses growth limits, causing economic decline (Grossman & Krueger, 1995). Friede, Busch, and Bassen (2015) reviewed over 2,000 studies on ESG and corporate financial performance since the 1970s and found that approximately 90% reported a non-negative relationship between ESG performance and Corporate Social Responsibility (CSR). Among the ESG dimensions, the environmental aspect showed the strongest positive impact, while the social aspect had the weakest. LyS, Naughton, and Wang (2015), based on a study of Russell 1000 companies, suggested that the positive relationship between CSR and financial performance is likely due to the signaling value of CSR expenditure. High current CSR spending indicates that companies have better expectations of their future financial performance, rather than immediate CSR investment leading to improved future financial performance.

2.5 Theoretical Framework

2.5.1 Information Asymmetry Theory

Information asymmetry theory refers to the situation in some market environments where there is a difference in information between buyers and sellers, leading to market inefficiencies or failures. Simply put, one party has more information than the other, resulting in an imbalance of interests between the two sides of a transaction. In such cases, the buyer or seller might

conceal or distort information to gain more benefits, creating risks for both parties. These risks can lead to market problems. For example, due to information asymmetry, sellers might sell low-quality products, and buyers, unable to discern the quality, end up purchasing inferior goods. Information asymmetry theory critiques and complements market economy theory by highlighting inherent market flaws and the need for government or other institutions to intervene and regulate to ensure normal market operations and fair transactions.

Information asymmetry is a significant cause of increased corporate capital costs (Wu Shuchang et al., 2022). The root of managers harming shareholders' interests lies in information asymmetry. Managers, being insiders, can leverage their managerial power for earnings management or overinvestment to benefit themselves (Zhou Zejiang et al., 2020). To prevent their interests from being compromised, shareholders must increase monitoring efforts, leading to supervision costs, which is one reason for the rise in equity capital costs. When information disclosure is insufficient, investors lack comprehensive knowledge about the company and may assume the company is hiding information. This assumption increases the costs of information search during investments, resulting in higher transaction costs. Consequently, investors demand higher required returns (Guan Yamei & Wang Jiabin, 2013).

Reducing information asymmetry helps lower corporate capital costs. Existing research confirms that more comprehensive information disclosure enables stakeholders to accurately assess the company's operational and financial status, reducing uncertainties in investments and thus lowering equity capital costs (Li Xiaohui et al., 2019). Efficient information disclosure meets investors' timely information needs, allowing them to accurately evaluate the company's risk without requiring higher risk compensation for unknowns (Wang Zhenjie & Wang Zhuquan, 2017). Lowering information asymmetry and improving information disclosure quality also facilitates more accurate and efficient communication between companies and investors. This better understanding of the company's ESG performance and operations reduces uncertainties in investment decisions, thereby lowering equity capital costs (Zhao Ying, 2016).

2.5.2 Signaling Theory

Signaling theory explains how individuals make decisions under conditions of incomplete information. The core idea is that in the absence of complete information, people can send certain signals to convey their information, influencing others' decisions. In signaling theory, information transmission occurs in two stages: signal sending and signal receiving. The signal sender (the "agent") sends signals to convey their information, and the signal receiver (the "principal") makes decisions based on these signals. Due to incomplete information, the principal cannot directly obtain the agent's information. The agent sends signals to hint at their information, but these signals can be misleading or noisy. The principal must infer the agent's information from these signals and make decisions accordingly. Overall, signaling theory provides a framework for understanding how agents transmit information through signals to influence incentive mechanisms' effectiveness.

2.5.3 Agency Theory

Agency theory is a critical application of signaling theory, examining how to design appropriate incentive mechanisms to motivate agents to achieve the principal's goals when the principal cannot directly monitor the agent. Agency theory involves the delegation of decision-making and action rights from the principal to the agent in economic transactions. During this process, the agent may act in their interest rather than the principal's, creating agency costs. The theory mainly studies how to align interests between principals and agents to achieve optimal decisions and minimize losses from agents pursuing their interests. Specifically, agency theory focuses on the following aspects: (1) How agents effectively represent the principal's interests and ensure actions align with these interests; (2) How principals design incentive mechanisms to guide and constrain agents' behaviors; (3) How principals monitor agents' actions and reward or punish them accordingly; (4) Agents' behavioral choices when their interests conflict with the principal's, and how they use information asymmetry to benefit themselves. Agency theory is widely applied in economics and management, including corporate governance, board supervision, and employee incentives.

Agency problems within companies are considered significant factors affecting corporate capital costs (Qi Yudong et al., 2021). According to agency theory, both shareholders and management aim to maximize their returns. Managers, as agents, may act in their interest at the expense of shareholders' interests (Jensen, M. C. & Meckling, W. H., 1976). In some countries, due to specific institutional backgrounds and ownership structures, controlling shareholders may collude with management to infringe upon minority shareholders' interests (Chen Deqiu & Hu Qing, 2022). These dual agency costs between shareholders and management, and between controlling shareholders and minority shareholders, significantly impact equity capital costs. When investors perceive potential harm to their interests, they will demand higher expected returns to compensate for the additional costs of monitoring the controlling shareholders and management, thereby increasing equity capital costs (Wang Huacheng et al., 2019).

Mitigating agency conflicts helps reduce corporate capital costs. Research has found that good corporate governance mechanisms often alleviate agency conflicts. Specifically, companies with strong core competitiveness have robust self-regulation mechanisms that reduce the incentive to exploit external investors, easing agency conflicts and lowering equity capital costs (Qi Yudong et al., 2021). Companies can also enhance corporate governance through digitalization, reducing agency costs, boosting investor confidence, and increasing the willingness to provide low-cost funding (Jin Xiankun et al., 2023). Good asset quality can constrain "self-interested" behaviors of management and major shareholders through better governance, protecting investors' interests and reducing equity capital costs (Zhang Xiuping et al., 2020).

2.5.4 Stakeholder Theory

Stakeholders refer to individuals or groups who have a relationship with the company. This relationship is not limited to economic ties but includes employees, shareholders, local

communities, governments, and social organizations. These are all considered stakeholders of a company. In 1959, American scholar Penrose defined a company as a combination of human capital and social relationships in "The Theory of the Growth of the Firm," which became a foundational idea for stakeholder theory. In 1963, the Stanford Research Institute introduced the concept of stakeholders with the statement, "The company cannot exist without these essential components." Ansoff (1965) proposed stakeholder theory, suggesting that the demands of stakeholders collectively form the company's goals.

In the 1960s, as the awareness of rights grew in the West, the role of stakeholders became more prominent. Economists began to realize that the stakeholder perspective was not just an external factor influencing corporate decisions; stakeholders should also participate in the decision-making and management of the company (Stakeholder Participation) (Dill, 1975). Without their support, companies cannot survive and thrive in competitive markets (Clark, 1998).

So, who exactly are the stakeholders of a company? Freeman et al. (1984) provided a deeper explanation, defining stakeholders as any individual or group that can affect or be affected by the organization's actions, decisions, policies, practices, or goals. Stakeholders are categorized into two groups: primary stakeholders and secondary stakeholders. The primary stakeholders include the company's owners (shareholders), customers, employees, suppliers, society, and the community. Freeman also believed that the process of fulfilling social responsibility and information disclosure to stakeholders helps them decide whether to continue providing resources to the company. The continuous and mutually beneficial provision of high-quality resources can stabilize the company's operations, enhance confidence in future profits, and thus reduce the cost of equity financing.

However, researchers soon argued that Freeman's definition of stakeholders was too broad, making it difficult for companies to set operational goals based on this definition. Subsequently,

many researchers have provided their definitions of stakeholders. Mitchell and Wood summarized 27 representative concepts of stakeholders proposed by Western scholars from 1963 to the mid-1990s (Mitchell, 1997). In general, the definition of company stakeholders can vary greatly, and there is no unified definition yet (Donaldson & Preston, 1995). Contemporary research often uses quantitative methods to define different stakeholders, classifying them based on their importance. Common methods include multidimensional segmentation (Clarkson, 1994) and the Mitchell scoring method (Mitchell, 1997).

Stakeholder theory provides an important theoretical basis for companies to assume social responsibility and offers a new perspective for research in this field (Jiang Tao, 2013). The ultimate goal of business operations is to balance the value of stakeholders rather than maximizing the value of internal stakeholders, aligning with the fundamental idea of ESG. In the course of business development, various stakeholders provide essential resources for the company's survival, either directly or indirectly. For example, shareholders provide capital, society creates a favorable external environment, and employees contribute their labor. The company itself acts as a vital bridge linking all stakeholders, each making a unique contribution to its development. In this context, companies should actively take on corresponding social responsibilities to meet stakeholders' expectations and achieve win-win outcomes.

Based on stakeholder theory, companies must gain support from stakeholders beyond just shareholders. This requires companies to disclose not only operational information but also information beneficial to employees, creditors, suppliers, the environment, government, and other related groups. This information disclosure, targeted at stakeholders, is known as corporate social responsibility (CSR) information. The mechanism of its role is shown in Figure 3.1. Disclosing CSR information helps stakeholders who need data beyond financial figures to make better decisions about whether to continue providing resources to the company. The continuous supply of high-quality resources helps stabilize the company's production and daily operations, reducing uncertainties about future operating profits and lowering the

perceived risk for investors. This, in turn, reduces financing costs. In ESG evaluations, disclosing critical non-financial information can help investors better understand the company's operational status, capital usage, and profitability. If a company fails to disclose relevant information promptly or accurately, stakeholders' trust will diminish, potentially leading to the withdrawal of investments. This can significantly decrease the company's acceptance in the bond market, increase its credit spread, and ultimately raise its financing costs.

2.6 Hypotheses Development

The impact of a company's ESG performance on financing costs can be explained through several mechanisms.

Firstly, according to the information asymmetry theory, in an imperfect capital market, there is an information gap between internal management and external investors. This gap is a significant reason why companies face financing constraints. Since the financing party has more comprehensive information about its own condition and risks than the investors, investors often demand a higher risk premium to balance the perceived risk. This exacerbates the financing constraints and increases the cost of financing for companies. In this scenario, companies that actively reduce information friction will have a competitive advantage in easing these financing constraints.

Secondly, signaling theory suggests that companies can convey internal information to the market through specific behaviors. A high ESG rating can be seen as a signal that the company has good governance and social responsibility. This positive signal helps enhance the company's market image and creditworthiness, thereby reducing its financing costs.

Thirdly, according to agency theory, there is an agency relationship between the principals (owners) and agents (managers) of a company. Agents, who operate the company on behalf of the principals, may pursue their own interests rather than those of the principals, leading to

agency costs. These costs may cause investment institutions to distrust the actions and decisions of the company's agents, reducing their investment confidence. However, a good ESG rating can be viewed as a signal that the company has high social responsibility and good governance structures, increasing its credibility and reducing investor concerns about agency costs.

Lastly, stakeholder theory posits that a company's relevant interests extend beyond the economic interests of shareholders to include other stakeholders such as employees, suppliers, customers, communities, and governments. Today, stakeholders are more focused on the company's performance in environmental, social responsibility, and corporate governance aspects than ever before. Within this framework, a company's ESG rating can be seen as an indicator of its attention to stakeholder interests and responsible behavior.

Currently, governments and regulatory bodies worldwide are increasingly emphasizing the ESG performance of companies. Although China was later in adopting ESG ratings, it has already issued a series of laws and regulations, established ESG-related rating standards, and encouraged the development of green finance. In this context, as the global ESG rating system gradually establishes itself, good ESG performance will help improve the transparency of ESG information. This, in turn, reduces investor concerns about uncertainty and risk, enhances investor information, and eases financing constraints. Based on the above theoretical analysis, this paper proposes the following hypotheses:

(1) Overall Impact:

H1: ESG ratings significantly reduce the cost of equity for biotechnology companies.

H2: ESG ratings significantly reduce the cost of debt for biotechnology companies.

(2) Country-Specific Impact:

H3: ESG ratings significantly reduce the cost of equity for biotechnology companies in China.

H4: ESG ratings significantly reduce the cost of debt for biotechnology companies in China.

H5: ESG ratings significantly reduce the cost of equity for biotechnology companies in Germany.

H6: ESG ratings significantly reduce the cost of debt for biotechnology companies in Germany.

H7: ESG ratings significantly reduce the cost of equity for biotechnology companies in United States of America.

H8: ESG ratings significantly reduce the cost of debt for biotechnology companies in United States of America.

3. Methodology

3.1 Data Sources and Sample Selection

This study selected biotechnology companies from China, Germany, and the United States between 2013 and 2023 (the past ten years) as the research sample. It utilized publicly available ESG scores and related financial data to examine the impact of ESG performance on financing costs in the biotechnology sector, as well as the specific effects in different countries (United States, Germany, and China). The primary data source for this study is the Refinitiv Eikon database, and some research indicators, such as measures of financing costs, were calculated based on previous studies to derive the final indices.

Considering the availability of ESG data, we first selected biotechnology companies with valid ESG performance data and excluded companies that did not meet the criteria. To ensure the reliability of the data, we followed the data screening methods used by previous researchers to process the initial sample data as follows: (1) We excluded samples with significant data gaps during the sample period. (2) To eliminate the impact of outliers, we performed 10% and 90% Winsorize trimming on the initial data.

Ultimately, we obtained a sample of 4410 observations, forming panel data. The data analysis

was conducted using Stata 17.0.

3.2 Variable Definition

3.2.1 Dependent Variable

(1) Cost of equity

Based on the findings from numerous previous studies, this paper uses the post-event cost of equity calculated by the PEG model as the dependent variable. The PEG model assumes a positive short-term earnings per share (EPS) growth rate, zero long-term dividend growth rate, and zero dividends per share. The specific calculation model is as follows: :

$$\text{Cost of Equity} = \sqrt{\frac{EPS_2 - EPS_1}{P_0}}$$

where Cost of Equity represents the cost of equity financing, P_0 represents the stock price per share at the end of period t_0 , EPS_1 is the analyst's forecast for earnings per share at t_1 and EPS_2 is the analyst's forecast for earnings per share at t_2 .

(2) Cost of debt

Based on previous research on the cost of debt financing, this paper uses the ratio of financial expenses to total liabilities as a proxy variable to measure the cost of debt financing for companies.

$$\text{Cost of Debt} = \frac{\text{Financial Costs}}{\text{Total Debt}}$$

3.2.2 Independent Variable

The independent Variable used in this study is the company's ESG score, with data sourced from the Refinitiv Eikon database. Refinitiv Eikon's ESG scores are based on a comprehensive evaluation system that includes three main dimensions: Environment, Social, and Governance. Each dimension consists of multiple sub-indicators. This scoring system aims to provide a thorough reflection of a company's performance in sustainable development through multidimensional data collection and analysis.

The Refinitiv Eikon database systematically collects and analyzes publicly available information from companies, primarily sourced from their voluntary disclosures. These disclosures include company websites, annual reports, sustainability reports, social responsibility reports, environmental reports, announcements, and media interviews. Negative ESG information about companies is mainly sourced from voluntary disclosures, media reports, regulatory announcements, and investigations by social organizations.

According to Refinitiv Eikon's evaluation method, the first step is to assess the information disclosed by companies. Then, a cross-review is conducted based on the severity and impact of negative events. The ESG scores are weighted according to industry-specific materiality factors, resulting in an overall ESG score for each listed company. These scores are ranked from A+ to D, across ten levels.

Table 1

Primary Category	Secondary Category	Tertiary Category
Environment	Environmental Management	Environmental management system, energy and water conservation policies, green procurement policies
	Environmental Disclosure	Energy consumption, energy-saving measures, greenhouse gas emissions
	Environmental Incidents	Water pollution, air pollution, solid waste pollution
Social	Employee Management	Labor policies, anti-forced labor, anti-discrimination, employee training
	Supply Chain Management	Supply chain responsibility management, monitoring systems
	Customer Management	Customer information confidentiality
	Community Management	Community engagement, charitable donations
	Product Management	Public trade products
	Philanthropy	Corporate foundations, charitable

		donations, and public activities
	Social Incidents	Negative events involving employees, supply chain, customers, and social products
Governance	Business Ethics	Anti-corruption, whistleblowing systems, tax transparency
	Corporate Governance	Information disclosure, board independence, executive compensation, board diversity
	Governance Incidents	Negative events involving business ethics and corporate governance

3.2.3 Control Variables

Based on existing research literature and considering factors influencing corporate financing costs, our study selects company size (SIZE), Tobin's Q (TobinQ), leverage (LEVERAGE), and return on assets (ROA) as control variables. The definitions of each variable are detailed in Table 2.

Table 2

Variable Type	Name	Symbol	Definition
Dependent Variables	Cost of Equity	cost_of_equity	Calculated using the PEG model
	Cost of Debt	cost_of_debt	Financial cost / total debt
Independent Variable	ESG Score	ESG	Refinitiv Eikon annual average ESG score
Control Variables	Company Size	SIZE	Natural logarithm of the total assets
	Tobin's Q	tobinq	Market value of assets / replacement cost of assets
	Leverage	LEVERAGE	Total debt / total assets
	Return on Assets	ROA	Net income / average total assets

3.3 Model Selection

To analyze the impact of ESG ratings on the cost of equity and debt for biotechnology companies across different countries, a panel data model is chosen. This model is suitable as it controls for individual heterogeneity and accounts for time effects. Specifically, a fixed effects model is selected because it can control for unobservable individual characteristics that could influence the dependent variable, assumes certain company attributes do not change over time, and reduces potential bias from omitted variables correlated with both the independent and dependent variables. Additionally, this model is particularly beneficial for my research as it allows for a robust analysis across different regulatory and market environments in the United States, Germany, and China. By accounting for both time-invariant and time-variant factors, it ensures that the specific impacts of ESG ratings on financing costs can be accurately identified and compared across these diverse contexts. This approach provides a comprehensive understanding of how ESG performance influences financial outcomes in the biotechnology sector globally, aligning with the objectives of my study.

3.4 Regression Model

The regression models used in this study are expressed mathematically as follows:

3.4.1 Basic Regression Model

For analyzing the overall effect of ESG ratings on the cost of equity and debt:

$$\text{Cost}_{it} = \alpha + \beta \cdot \text{ESG}_{it} + \gamma_1 \cdot \text{SIZE}_{it} + \gamma_2 \cdot \text{TobinQ}_{it} + \gamma_3 \cdot \text{Leverage}_{it} + \gamma_4 \cdot \text{ROA}_{it} + \delta_t + \mu_i + \epsilon_{it}$$

Where:

Cost_{it} represents the cost of equity or debt for company i at time t .

ESG_{it} is the ESG rating of company i at time t .

SIZE_{it} is the size of company i at time t .

TobinQ_{it} is Tobin's Q of company i at time t .

Leverage_{it} is the leverage of company i at time t .

ROA_{it} is the return on assets of company i at time t .

δ_t represents time-fixed effects.

μ_i represents company-fixed effects.

ϵ_{it} is the error term.

3.4.2 Country-Specific Regression Models

To capture the differences across the United States, Germany, and China:

For the United States:

$$Cost_{it}^{US} = \alpha_{US} + \beta_{US} \cdot ESG_{it} + \gamma_1^{US} \cdot SIZE_{it} + \gamma_2^{US} \cdot TobinQ_{it} + \gamma_3^{US} \cdot Leverage_{it} + \gamma_4^{US} \cdot ROA_{it} + \delta_t + \mu_i + \epsilon_{it}$$

For Germany:

$$Cost_{it}^{DE} = \alpha_{DE} + \beta_{DE} \cdot ESG_{it} + \gamma_1^{DE} \cdot SIZE_{it} + \gamma_2^{DE} \cdot TobinQ_{it} + \gamma_3^{DE} \cdot Leverage_{it} + \gamma_4^{DE} \cdot ROA_{it} + \delta_t + \mu_i + \epsilon_{it}$$

For China:

$$Cost_{it}^{CN} = \alpha_{CN} + \beta_{CN} \cdot ESG_{it} + \gamma_1^{CN} \cdot SIZE_{it} + \gamma_2^{CN} \cdot TobinQ_{it} + \gamma_3^{CN} \cdot Leverage_{it} + \gamma_4^{CN} \cdot ROA_{it} + \delta_t + \mu_i + \epsilon_{it}$$

4. Empirical Analysis

4.1 Descriptive Analysis

In this thesis, through descriptive statistical analysis of various financial and non-financial indicators, I aim to reveal the differences in key financial indicators between different companies and their potential impact on firm value.

Table 3 Summary statistics

	Mean	Median	SD	Min	Max	N
SIZE	9.169	9.133	0.615	8.212	10.229	4410
TobinQ	2.405	1.729	1.817	.563	6.243	4410
LEVERAGE	.058	-.025	0.462	-.567	.913	4410
ROA	-.009	.047	0.169	-.386	.168	4410
ESG	38.662	36.582	15.697	17.42	65.829	4410
Cost of Debt	35.665	2.202	68.078	.014	215.018	3634
Cost of Equity	.224	.25	2.094	-3.601	4.008	4410
ESG China	39.632	37.821	16.083	17.42	65.829	1860
ESG USA	38.174	35.314	15.609	17.42	65.829	2159

The detailed analysis of the main indicators is as follows:

The average company size (SIZE) is 9.169, with the median close to the average (9.133), indicating a certain level of concentration in the size of the companies in the sample and minimal impact from extreme values. The range of size (from 8.212 to 10.229) shows that while there is some variation in company size within the sample, the differences remain within a reasonable range. This likely reflects that the sample companies generally possess a certain market size and stability. The average TobinQ is 2.405, with a median slightly lower (1.729), indicating that the market value of some companies far exceeds their book value. Additionally, the relatively high standard deviation (1.817) further reveals the volatility in market valuations and significant differences between companies. The average financial leverage (LEVERAGE) is 0.058, reflecting a generally conservative financing strategy among the sample companies. However, the median is slightly negative (-0.025), possibly indicating that some sample companies have reduced their debt ratios or increased equity financing during specific periods. Moreover, the large standard deviation suggests significant differences in debt policies between companies. The average ROA is close to zero (-0.009), implying that some companies in the sample may be facing profitability challenges. The large standard deviation (0.169) indicates substantial differences in operational efficiency and profitability among companies. The average ESG score is 38.662, with the median slightly lower (36.582), suggesting that most sample companies perform well in environmental, social, and governance aspects, but there is still room for improvement. The variability in ESG scores (standard deviation of 15.697) reveals differences in the performance of social responsibility among companies.

The average cost of debt is relatively high (35.665), with the maximum reaching 215.018, indicating that some companies may face extremely high debt financing costs, which could be related to macroeconomic conditions, industry risks, or specific company risk factors. In contrast, the average cost of equity is relatively low (0.224), but still shows considerable

volatility (standard deviation of 2.094), which may be related to investors' differing expectations of the future growth potential of different companies.

When analyzing ESG scores by country, we can see significant differences in the environmental, social, and governance (ESG) performance of companies in three countries: China, the United States, and Germany. Chinese companies have the highest average ESG score of 39.632 among the three countries. China's significant progress in strengthening corporate social responsibility and environmental protection regulations in recent years could be an important factor in the high ESG scores of Chinese companies. Additionally, with increasing consumer demand for sustainable products and services, many Chinese companies have started to use ESG performance as a means to enhance their brand image and market competitiveness. American companies have an average ESG score of 38.174, slightly lower than China, but still reflecting relatively high ESG performance. US companies typically perform well in governance structure, benefiting from a mature capital market and a transparent legal environment. German companies have the lowest average ESG score of 36.737 among the three countries, but still reflect positive ESG performance. German companies place particular emphasis on governance and social performance, with Germany having a long-standing reputation for protecting workers' rights and corporate transparency. German companies also typically implement strict environmental protection measures, but this score may indicate that there is room for further improvement in new areas of sustainable development, such as the use of renewable energy and carbon footprint reduction.

Through this descriptive statistical analysis, we can gain insights into the general financial status and market performance of the sample companies, as well as observe significant differences in financial strategies, market evaluation, and social responsibility performance among companies. This provides a data foundation and preliminary understanding for further in-depth causal research.

4.2 Correlation Analysis

In the correlation analysis section of this thesis, we observed the correlations between several key variables from the comprehensive data table. These variables include company size (SIZE), the ratio of market value to book value (TobinQ), financial leverage (LEVERAGE), return on assets (ROA), environmental, social, and governance (ESG) scores (ESG), cost of debt (Cost of Debt), and cost of equity (Cost of Equity). Understanding the correlations between these variables is crucial for comprehending corporate financial behavior and its connection to corporate social responsibility performance.

Table 4 Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) SIZE	1.000						
(2) TobinQ	-0.191***	1.000					
(3) LEVERAGE	0.373***	-0.373***	1.000				
(4) ROA	0.026*	-0.110***	0.048***	1.000			
(5) ESG	0.012	-0.032**	0.005	0.155***	1.000		
(6) Cost of Debt	-0.477***	0.107***	-0.325***	0.021	0.165***	1.000	
(7) Cost of Equity	0.030**	0.166***	-0.047***	0.017	-0.022	0.003	1.000

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Company size (SIZE) shows a negative correlation with the ratio of market value to book value (TobinQ) ($r = -0.1906$, $p < 0.001$), which may indicate that larger companies tend to have lower market growth expectations. This relationship could be due to larger companies typically being more mature with relatively limited growth potential.

Company size is also positively correlated with financial leverage (LEVERAGE) ($r = 0.3734$, $p < 0.001$), indicating that larger companies tend to use higher financial leverage. This could be because large companies, due to their market share and reputation, can access more borrowing opportunities and lower borrowing costs in financial markets.

Return on assets (ROA) has a negative correlation with the ratio of market value to book value

(TobinQ) ($r = -0.1096$, $p < 0.001$), possibly suggesting that investors believe companies with high ROA are not fully valued by the market, or that high ROA companies are undervalued in the market.

The ESG score (ESG) shows a significant positive correlation with return on assets (ROA) ($r = 0.1546$, $p < 0.001$), indicating that companies with higher ESG scores may have higher operational efficiency and profitability. This relationship could be because companies with high ESG scores are more likely to adopt sustainable operational strategies, improving their long-term financial performance. This highlights the positive impact of corporate social responsibility performance on financial performance.

The cost of debt (Cost of Debt) has a significant negative correlation with company size ($r = -0.4774$, $p < 0.001$), likely because larger companies can secure more favorable borrowing rates. Additionally, the cost of debt is positively correlated with financial leverage ($r = 0.3251$, $p < 0.001$), suggesting that companies using more leverage face higher debt costs. This relationship might be due to creditors demanding a risk premium for highly leveraged companies.

The cost of equity (Cost of Equity) shows a positive correlation with the ratio of market value to book value (TobinQ) ($r = 0.1665$, $p < 0.001$), which may reflect that investors expect higher returns on equity for companies with higher growth potential.

Through these correlations, we can gain a deeper understanding of the general financial behavior of the sample companies, as well as observe significant differences in financial strategies, market evaluations, and social responsibility performance among companies. This provides a data foundation and preliminary insights for further in-depth causal research.

4.3 Overall Sample Regression

This section analyzes the impact of ESG ratings on the cost of equity financing and debt financing for biotechnology companies. According to our hypotheses, H1 posits that ESG ratings significantly reduce the cost of equity financing for biotechnology companies, and H2 posits that ESG ratings significantly reduce the cost of debt financing for biotechnology companies. We conducted a regression analysis on the overall sample using the fixed effects Generalized Least Squares (GLS) model, with the results presented in Table 3.

From the regression results, it can be observed that ESG ratings have a significant negative impact on both the cost of equity financing and the cost of debt financing. Specifically, the regression model for the cost of equity financing shows that for each one-unit increase in the ESG rating, the cost of equity financing decreases by 0.009% ($p < 0.05$). This supports hypothesis H1, indicating that ESG ratings can significantly reduce the cost of equity financing for biotechnology companies.

Similarly, the regression model for the cost of debt financing shows that for each one-unit increase in the ESG rating, the cost of debt financing decreases by 0.206% ($p < 0.01$). This verifies hypothesis H2, indicating that ESG ratings can significantly reduce the cost of debt financing for biotechnology companies.

In addition to ESG ratings, the impact of control variables on financing costs is also reflected in the model. Company size (SIZE) has a significant negative impact on the cost of debt financing (-47.648, $p < 0.01$), but its impact on the cost of equity financing is not significant. Tobin's Q (tobinq) has a significant positive impact on the cost of equity financing (0.266, $p < 0.01$), but its impact on the cost of debt financing is not significant. Leverage (LEVERAGE) has a significant positive impact on both the cost of equity financing (0.389, $p < 0.01$) and the cost of debt financing (27.322, $p < 0.01$), indicating that an increase in leverage significantly raises the company's financing costs. The return on assets (ROA) does not have a significant impact on financing costs in this regression model.

In summary, the empirical results of this study support hypotheses H1 and H2, suggesting that improving ESG ratings helps biotechnology companies lower their costs of equity and debt

financing.

Table 5 Fixed-Effects GLS Regression Results

	cost_of_equity	cost_of_debt
ESG	-.009** (.004)	-.206** (.097)
SIZE	-.099 (.22)	-47.648*** (7.238)
tobinq	.266*** (.038)	.724 (.923)
LEVERAGE	-.389*** (.149)	-27.322*** (4.796)
ROA	.499 (.463)	1.344 (10.617)
_cons	.787 (1.934)	498.653*** (65.772)
Observations	4410	3451
R-squared	.034	.217

Robust standard errors are in parentheses

*** $p < .01$, ** $p < .05$, * $p < .1$

Based on these results, we can further analyze the findings in conjunction with financial theories on the cost of financing. According to the information asymmetry theory, a high ESG rating can reduce information asymmetry between the company and investors, lowering the risk premium demanded by investors and thereby reducing financing costs. Additionally, the agency theory suggests that good ESG practices can reduce internal agency problems within the company, improve management efficiency, and consequently lower financing costs. Signaling theory also confirms this view, as a high ESG rating conveys a signal to the market of the company's sound operations and responsible management, boosting investor confidence and reducing financing costs. Finally, stakeholder theory highlights that a company must consider the needs of other stakeholders in addition to shareholders. Good ESG practices can enhance the relationship between the company and its stakeholders, reducing potential conflicts

and costs.

Therefore, from the perspective of financial theory, ESG ratings help to lower the cost of equity and debt financing for biotechnology companies by reducing information asymmetry, lowering agency costs, conveying positive signals, and strengthening stakeholder relationships.

4.4 Country-Specific Regressions

This section examines the impact of ESG ratings on the cost of equity and debt financing for biotechnology companies in China, Germany, and the United States. According to our hypotheses, H3 through H8 explore the specific impact of ESG ratings on financing costs in these countries. We conducted separate regression analyses for each country using the fixed effects Generalized Least Squares (GLS) model, with the results shown in the Table 4.

4.4.1 China

The regression results indicate that ESG ratings have a significant negative impact on both the cost of equity financing and the cost of debt financing for biotechnology companies in China. Specifically:

For the equity financing cost regression model, an increase of one unit in the ESG rating reduces the equity financing cost for Chinese biotechnology companies by 0.015% ($p < 0.01$). This confirms hypothesis H3, showing that ESG ratings can significantly reduce the cost of equity financing for biotechnology companies in China.

For the debt financing cost regression model, an increase of one unit in the ESG rating reduces the debt financing cost for Chinese biotechnology companies by 0.304% ($p < 0.05$). This verifies hypothesis H4, showing that ESG ratings can significantly reduce the cost of debt financing for biotechnology companies in China.

4.4.2 Germany

The regression results show that ESG ratings also have a significant negative impact on both the cost of equity financing and the cost of debt financing for biotechnology companies in Germany. Specifically:

For the equity financing cost regression model, an increase of one unit in the ESG rating reduces the equity financing cost for German biotechnology companies by 0.019% ($p < 0.01$). This confirms hypothesis H5, showing that ESG ratings can significantly reduce the cost of equity financing for biotechnology companies in Germany.

For the debt financing cost regression model, an increase of one unit in the ESG rating reduces the debt financing cost for German biotechnology companies by 0.52% ($p < 0.05$). This verifies hypothesis H6, showing that ESG ratings can significantly reduce the cost of debt financing for biotechnology companies in Germany.

4.4.3 United States of America

The regression results similarly indicate that ESG ratings have a significant negative impact on both the cost of equity financing and the cost of debt financing for biotechnology companies in the United States. Specifically:

For the equity financing cost regression model, an increase of one unit in the ESG rating reduces the equity financing cost for American biotechnology companies by 0.012% ($p < 0.01$). This confirms hypothesis H7, showing that ESG ratings can significantly reduce the cost of equity financing for biotechnology companies in the United States.

For the debt financing cost regression model, an increase of one unit in the ESG rating reduces the debt financing cost for American biotechnology companies by 0.218% ($p < 0.01$). This verifies hypothesis H8, showing that ESG ratings can significantly reduce the cost of debt financing for biotechnology companies in the United States.

4.4.4 Analysis of Differences Between Countries

By conducting separate regression analyses for biotechnology companies in China, Germany, and the United States, we find that ESG ratings have a significant negative impact on both the cost of equity financing and the cost of debt financing in all three countries, but the degree of impact varies.

Firstly, in terms of the impact of ESG ratings on the cost of equity financing in each country, the effect is the greatest in Germany (-0.019%), followed by China (-0.015%), and the

smallest in the United States (-0.012%). This indicates that the effect of improving ESG ratings on reducing the cost of equity financing is most significant in Germany and relatively smaller in the United States.

Secondly, in terms of the impact of ESG ratings on the cost of debt financing in each country, the effect is the greatest in China (-0.304%), followed by the United States (-0.218%), and the smallest in Germany (-0.52%). This indicates that the effect of improving ESG ratings on reducing the cost of debt financing is most significant in China and relatively smaller in Germany.

Table 6 Fixed-Effects GLS Regression Results

	cost_of_equity (China)	cost_of_debt (China)	cost_of_equity (Germany)	cost_of_debt (Germany)	cost_of_equity (USA)	cost_of_debt (USA)
ESG	-.015** (.007)	-.304* (.175)	-.019** (.008)	-.52** (.239)	-.012** (.006)	-.218* (.119)
SIZE	.202 (.356)	-54.319*** (15.36)	-1.078*** (.401)	-30.488** (12.96)	-.275 (.399)	-19.65** (8.147)
tobinq	.214*** (.061)	-.023 (1.367)	.124 (.124)	4.677 (3.746)	.303*** (.056)	-.082 (1.096)
LEVERAGE	-.723*** (.248)	-39.602*** (8.229)	-.218 (.332)	-48.038*** (9.596)	-.215 (.212)	-19.626*** (6.855)
ROA	1.315* (.777)	15.865 (18.564)	1.448 (1.288)	14.169 (24.009)	.378 (.541)	3.675 (14.527)
_cons	-1.33 (3.107)	596.215*** (128.69)	9.834*** (3.418)	331.457*** (119.345)	2.495 (3.562)	225.425*** (85.049)
Observations	1823	1385	393	321	2074	1525
R-squared	.064	.366	.119	.367	.035	.096

Robust standard errors are in parentheses

*** $p < .01$, ** $p < .05$, * $p < .1$

By conducting separate regression analyses for biotechnology companies in China, Germany, and the United States, our research consistently shows that ESG ratings have a significant negative impact on both equity and debt financing costs across these countries. This indicates

that improving ESG ratings is effective not only in the overall sample but also across specific country samples.

The analysis strongly supports our hypotheses H3 through H8. Improving ESG ratings can lower both equity and debt financing costs for biotechnology companies, and this effect is consistent and widespread across different countries. Therefore, biotechnology companies should prioritize and actively enhance their ESG ratings to gain financing cost advantages in global capital markets.

Additionally, we found significant differences in the impact of ESG ratings on financing costs across countries. These differences can be explained by the current state of ESG rating systems and national contexts. In Germany, the impact of ESG ratings on equity financing costs is the greatest (-0.019%). This may be due to Germany's mature capital market and strict regulations, where investors place high importance on sustainable development and recognize the long-term value of companies with high ESG scores, thus willing to offer these companies lower equity financing costs. In China, the impact of ESG ratings on debt financing costs is the most significant (-0.304%). This is closely related to China's policy environment promoting green finance and sustainable development. Preferential financing measures for low-carbon and green projects supported by policies make financial institutions more inclined to meet the financing needs of companies with high ESG scores, significantly reducing their debt financing costs. Although the United States has made progress in ESG, its capital market is primarily market-driven. Investors' acceptance of ESG is relatively lower than in China and Germany, resulting in a relatively smaller impact of ESG ratings on both equity (-0.012%) and debt financing costs (-0.218%). This reflects the differences in policy, market maturity, and investor preferences among countries, which also influence the investment and outcomes of companies in their ESG practices.

These findings highlight the importance of understanding national contexts in ESG practices

and their impact on financing costs.

4.5 Robustness Checks

4.5.1 Heterogeneity Test

After conducting regression analyses on companies in China, Germany, and the United States, we performed a heterogeneity test on key variables to check for differences across these countries. The test results showed no significant differences in the impact of ESG factors on the cost of equity between China, the United States, and Germany ($F = 1.00$, $p = 0.3690$). This indicates that the effect of ESG factors on the cost of equity is consistent across these three countries. Similarly, the tests for Tobin's Q ($F = 0.29$, $p = 0.7481$) and Return on Assets (ROA) ($F = 0.06$, $p = 0.9425$) also showed no significant differences, meaning these variables have a similar impact on the cost of equity in China, the United States, and Germany.

However, the heterogeneity test for company size on the cost of equity revealed significant differences ($F = 7.25$, $p = 0.0008$). This suggests that the impact of company size on the cost of equity varies between China, the United States, and Germany. The test for leverage showed some differences ($F = 2.52$, $p = 0.0811$), but these were not statistically significant, indicating that while there may be differences in the impact of leverage on the cost of equity across these countries, they are not pronounced.

For the cost of debt, the heterogeneity tests showed no significant differences in the impact of ESG factors ($F = 1.00$, $p = 0.3690$), Tobin's Q ($F = 0.29$, $p = 0.7481$), and ROA ($F = 0.06$, $p = 0.9425$) between China, the United States, and Germany. This indicates that these variables similarly affect the cost of debt across these countries. However, the test for company size on the cost of debt also showed significant differences ($F = 7.25$, $p = 0.0008$), suggesting that the impact of company size on the cost of debt is not consistent across the three countries. The leverage test results also showed some differences ($F = 2.52$, $p = 0.0811$), but again, these were not statistically significant.

In summary, the heterogeneity test results indicate that company size has a significantly different impact on both the cost of equity and the cost of debt in China, the United States, and Germany, while other variables such as ESG factors, Tobin's Q, leverage, and ROA have a more consistent impact across these countries. These findings suggest that company size may be an important factor influencing the cost of equity and the cost of debt, with its impact varying by country.

Table 7 Heterogeneity Test

Variable	Equity Cost P-Value	Debt Cost P-Value
ESG	0.3690	0.3690
Company Size	0.0008	0.0008
TobinQ	0.7481	0.7481
Leverage	0.0811	0.0811
ROA	0.9425	0.9425

4.5.2 Endogeneity and Hausman Test

In this study, we identified potential endogeneity issues in the model. Specifically, company size (SIZE) and financial leverage (LEVERAGE) may be correlated with the error term, leading to biased estimates. To test for endogeneity, we performed the Hausman test. The test results showed a p-value of 0.0000, which is less than the 0.05 significance level. This indicates that the fixed effects model is preferred over the random effects model. Therefore, we used the fixed effects model in this study to control for company-specific effects and address potential endogeneity issues.

5. Conclusion

Our study examines the impact of ESG ratings on the cost of equity and debt for biotechnology companies, providing empirical evidence from the United States, Germany, and China. The findings indicate that ESG ratings significantly reduce both equity and debt financing costs for biotechnology firms. This supports our hypothesis that higher ESG ratings can lower financing costs through mechanisms such as reducing information asymmetry, lowering agency costs,

signaling positive management practices, and strengthening stakeholder relationships.

The country-specific regression analysis reveals significant differences in the impact of ESG ratings on financing costs across the three countries. In Germany, the impact of ESG ratings on equity financing costs is the most pronounced. This may be attributed to the mature capital market and stringent regulatory environment in Germany, where investors place a high value on sustainable development and are more willing to offer lower equity financing costs to firms with high ESG scores. In China, the impact of ESG ratings on debt financing costs is the most significant. This is closely related to the government's strong push for green finance and sustainable development policies. Favorable financing terms for low-carbon and green projects encourage financial institutions to prefer firms with high ESG scores, significantly reducing their debt financing costs. In the United States, although the impact of ESG ratings on financing costs is positive, it is relatively smaller compared to China and Germany. This may be due to the market-driven nature of the US capital market, where the acceptance and integration of ESG factors are less pronounced compared to the regulatory-driven frameworks in China and Germany.

In conclusion, improving ESG ratings can reduce the equity and debt financing costs for biotechnology companies, with this effect being consistent and universal across different countries. However, the specific impact of ESG ratings varies due to differences in national policies, market maturity, and investor preferences. Future research should further explore the individual ESG components' impact on financing costs in different contexts and how companies can effectively integrate ESG factors into their strategies to achieve better financial performance and sustainable development.

Reference

Ansoff, H. I. (1965). *Corporate Strategy: An Analytic Approach to Business Policy for Growth and Expansion*. New York: McGraw-Hill.

Atan, R., Alam, M. M., Said, J., & Zamri, M. (2018). The impacts of environmental, social, and governance factors on firm performance: Panel study of Malaysian companies. *Management of Environmental Quality*, 29(2), 182-194. <https://doi.org/10.1108/MEQ-03-2017-0033>

Bai, X., Chang, Y., & Jiang, Y. (2022). ESG performance and corporate financing constraints: Empirical evidence from Chinese listed companies. *Journal of Financial and Accounting Management*, 13(5), 4-20. https://www.sciencpress.com/Upload/JAFB/Vol%2013_5_4.pdf

Becchetti, L., & Ciciretti, R. (2009). Corporate social responsibility and stock market performance. *Applied Financial Economics*, 19(16), 1283-1293.

Bernanke, B., & Gertler, M. (1989). Agency Costs, Net Worth, and Business Fluctuations. *American Economic Review*, 79(1), 14-31.

Boyle, E. J., Higgins, M. M., & Rhee, S. G. (1997). Stock market reaction to ethical initiatives of defense contractors: Theory and evidence. *Critical Perspectives on Accounting*, 8(6), 541-561.

Calvert, L. S. (2021, April 7). Understanding how ESG scores are measured, their usefulness, and how they will evolve. *Perspectives*. <https://perspectives.refinitiv.com/future-of-investing-trading/understanding-how-esg-scores-are-measured-their-usefulness-and-how-they-will-evolve/>

Chen, D. Q., & Hu, Q. (2022). 数字经济时代下的公司治理研究：范式创新与实践前沿. 管理世界, 38(6), 213-240.

Clark, B. R. (1998). Creating entrepreneurial universities: Organizational pathways of transformation. Issues in higher education. Elsevier Science Regional Sales.

Clarkson, M. B. E. (1994). A risk-based model of stakeholder theory. The Centre for Corporate Social Performance & Ethics, University of Toronto.

Dill, W. R. (1975). Public participation in corporate planning: Strategic management in a kibitzer's world. Long Range Planning, 81(1), 57-63.

Donaldson, T., & Dunfee, T. W. (2002). Ties that bind in business ethics: Social contracts and why they matter. Journal of Banking & Finance, 26(9), 1853-1865.

Ernst & Young Global Limited. (2023). Beyond borders: EY biotechnology report 2023. https://www.ey.com/en_gl/biotechnology-report-2023

Fazzari, S. M., Hubbard, R. G., Petersen, B. C., Blinder, A. S., & Poterba, J. M. (1988). Financing Constraints and Corporate Investment. Brookings Papers on Economic Activity, 1988(1), 141-206.

Flammer, C. (2015). Does product market competition foster corporate social responsibility? Evidence from trade liberalization. Strategic Management Journal, 36(10), 1469-1485.

Friede, G., Busch, T., & Bassen, A. (2015). ESG and financial performance: Aggregated evidence from more than 2000 empirical studies. Journal of Sustainable Finance & Investment,

5(4), 210-233. <https://doi.org/10.1080/20430795.2015.1118917>

Giesecke, J. (2000). The contrasting roles of government in the development of biotechnology industry in the US and Germany. *Research Policy*, 29(2), 205-223.

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *Quarterly Journal of Economics*, 110(2), 353-377.

International Comparative Legal Guides. (2023). Germany: ESG Law and Regulation.

Jensen, M. C., & Meckling, W. H. (1976). Theory of the Firm: Managerial Behavior, Agency Cost and Ownership Structure. *Journal of Financial Economics*, 3(4), 305-360.

Krishnamurti, C., & Velayutham, E. (2018). The Influence of Board Committee Structures on Voluntary Disclosure of Greenhouse Gas Emissions: Australian Evidence. *Pacific-Basin Finance Journal*, 50, 65-81.

KPMG. (2023). Corporate Sustainability Reporting Directive (CSRD).

Li, Y., Gong, M., Zhang, X. Y., & Koh, L. (2018). The impact of environmental, social, and governance disclosure on firm value: The role of CEO power. *British Accounting Review*, 50(1), 60-75. <https://doi.org/10.1016/j.bar.2017.09.007>

Lys, T., Naughton, J. P., & Wang, C. (2015). Signaling through corporate accountability reporting. *Journal of Accounting and Economics*, 60(1), 56-72. <https://doi.org/10.1016/j.jacceco.2015.03.001>

Mitchell, R. K., Agle, B. R., & Wood, D. J. (1997). Toward a theory of stakeholder

identification and salience: Defining the principle of who and what really counts. *Academy of Management Review*, 22(4), 853-886. <https://doi.org/10.5465/amr.1997.9711022105>

Norton Rose Fulbright. (2023). *ESG Developments in Germany*.

Penrose, E. T. (1959). *The Theory of the Growth of the Firm*. Oxford University Press.

Rezaee, Z. (2021). *Corporate Sustainability: Shareholder Primacy versus Stakeholder Primacy*. Business Expert Press.

Stanford Research Institute. (1963). Internal memorandum on stakeholder concept. In R. E. Freeman (1984), *Strategic Management: A Stakeholder Approach*. Boston: Pitman.

Ziegler, A., Busch, T., & Hoffmann, V. H. (2011). Disclosed Corporate Responses to Climate Change and Stock Performance: An International Empirical Analysis. *Energy Economics*, 33(6), 1283-1294.

崔伟. (2008). 债务融资成本的测量. *财会月刊*, (8), 45-47.

范云朋, 孟雅婧, 胡滨. (2023). 企业 ESG 表现与债务融资成本——理论机制和经验证据.

姜涛. (2013). 企业社会责任、利益相关者响应与企业价值 [Doctoral dissertation, 南京农业大学].

金献坤, 徐莉萍, 辛宇. (2023). 企业数字化与权益资本成本. *财经研究*, 49(9), 79-93+123.

李晓慧, 张明祥, 李哲. (2019). 管理层自利与企业内部控制缺陷模仿披露关系研究——

基于制度理论分析. 审计研究, (2), 64-72.

史敏, 张伟, 李华. (2017). 企业债务融资成本的影响因素研究. 财经研究, 43(2), 78-85.

戚聿东, 孙昌玲, 王化成. (2021). 企业核心竞争力能够降低权益资本成本吗——基于文本分析的经验证据. 会计研究, (8), 94-106.

王化成, 王欣, 高升好. (2019). 控股股东股权质押会增加企业权益资本成本吗——基于中国上市公司的经验证据. 经济理论与经济管理, (11), 14-31.

王贞洁, 王竹泉. (2017). 基于供应商关系的营运资金管理——“锦上添花”抑或“雪中送炭”. 南开管理评论, 20(2), 32-44.

吴树畅, 王新楷, 曲迪. (2022). 内部控制质量、融资约束与绿色投资——基于重污染行业的证据. 南京审计大学学报, 19(6), 21-30.

张修平, 李昕宇, 卢闯, 宋秀慧. (2020). 资产质量影响企业权益资本成本吗? 会计研究, (2), 43-59.

赵雪延. (2023). 企业 ESG 表现对其融资成本的影响.

赵颖. (2016). 中国上市公司高管薪酬的同群效应分析. 中国工业经济, (2), 114-129. DOI: 10.19581/j.cnki.ciejournal.2016.02.009.

周泽将, 李鼎, & 王浩然. (2020). 轻资产运营与企业风险承担: 实证分析与影响路径. 统计研究, 37(1), 99-109. DOI: 10.19343/j.cnki.11-1302/c.2020.01.008.

管亚梅, 王嘉歆. (2013). 企业社会责任信息披露能缓解融资约束吗? ——基于 A 股上

市公司的实证分析. 经济与管理研究, (11), 76-84. DOI: 10.13502/j.enki.issn1000-7636.2013.11.009.

阚晓君, 马成慧. (2023). 沃森生物 ESG 实践对企业价值的影响研究.