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Sectoral Heterogeneity in Corporate Biodiversity Disclosure: Evidence from Chinese Listed Companies Across Industries, 2001–2023

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ABSTRACT

This study examines sectoral heterogeneity in corporate biodiversity disclosure (CBD) among Chinese listed firms over the period 2001–2023. Drawing on stakeholder, institutional, and resource dependency theories, it investigates how environmental exposure, ownership structures, and market dynamics influence biodiversity risk recognition and disclosure intensity across 19 industries. Based on a longitudinal dataset comprising 57,367 firm-year observations, the findings reveal substantial variation in CBD practices. Environmentally sensitive sectors such as agriculture, mining, and construction demonstrate higher disclosure levels, while service-oriented industries often engage in symbolic reporting. Temporal analysis highlights accelerated CBD growth in IT and finance sectors, challenging conventional assumptions about ecological proximity. The study offers policy insights for tailoring biodiversity reporting frameworks to sector-specific characteristics in emerging markets.

JEL Classification: Q56, M14, L16, G38, O13

1 | Introduction

Biodiversity degradation has become a pressing global concern, with far-reaching implications for ecological stability and corporate sustainability. In recent years, biodiversity-related risks have gained prominence in environmental, social, and governance frameworks, prompting firms to disclose their dependencies and impacts on natural ecosystems. Corporate biodiversity disclosure (CBD), defined as the process by which companies transparently report their impacts, risks, dependencies, and strategies related to biodiversity, serves as a strategic mechanism for communicating environmental accountability, risk management, and long-term value creation.

Despite growing international momentum—driven by frameworks such as the Taskforce on Nature-related Financial Disclosures (TNFD) and the International Sustainability Standards Board (ISSB)—CBD practices remain uneven across sectors, particularly in emerging economies. Existing research on corporate environmental disclosure has established that firms respond to stakeholder pressures, institutional environments, and resource dependencies when developing sustainability reporting practices. However, three critical knowledge gaps persist. First, current literature treats biodiversity disclosure as largely homogeneous across sectors, overlooking how fundamental operational differences, environmental exposure profiles, and stakeholder configurations shape reporting intensity and authenticity. Second, temporal evolution patterns of CBD adoption across different industry types remain unexplored, particularly in contexts undergoing rapid regulatory transformation and economic development. Third, policy frameworks continue to apply uniform disclosure standards despite likely sectoral variation in adoption capacity, materiality assessments, and stakeholder pressures.

China, as a rapidly industrializing nation with diverse ecological zones and evolving regulatory landscapes, presents a compelling context for addressing these gaps. The Chinese market encompasses sectors ranging from direct resource extraction to knowledge-intensive services, operating under a distinctive institutional framework that combines state ownership structures with market mechanisms. This heterogeneity, combined with China's recent elevation of biodiversity protection through the Kunming COP15 conference and ecological civilization policy initiatives, creates conditions for examining how sectoral characteristics interact with institutional pressures to shape disclosure behavior.

This study investigates the extent and drivers of sectoral heterogeneity in CBD among Chinese listed companies from 2001 to 2023, a period encompassing China's accession to the World Trade Organization, its emergence as a global manufacturing center, and its transition toward environmental governance integration. Specifically, this research addresses three interrelated questions. First, to what extent do sectoral characteristics explain heterogeneity in corporate biodiversity risk recognition and disclosure intensity across Chinese industries, and does environmental exposure serve as the primary differentiating factor in adoption patterns? Second, how do temporal evolution patterns of biodiversity awareness adoption differ across sectors, and what sectoral characteristics predict accelerating versus steady growth trajectories in disclosure practices? Third, what are the policy implications of observed sectoral heterogeneity patterns, and how should regulatory frameworks be differentiated to optimize biodiversity disclosure adoption across industries with varying environmental exposure profiles?

Drawing on stakeholder theory, institutional theory, and resource dependency theory, the study integrates these complementary theoretical lenses to explain why certain industries disclose biodiversity risks more comprehensively than others. Using a robust longitudinal dataset of 57,367 firm-year observations across 19 sectors, the analysis explores how environmental exposure, ownership structures, and market dynamics shape disclosure behavior over time.

The investigation yields several important findings that challenge conventional assumptions about environmental disclosure patterns. Sectors with direct ecological footprints—such as agriculture, mining, and construction—exhibit higher CBD adoption rates, confirming the environmental exposure hypothesis. However, industries with indirect environmental links demonstrate divergent patterns. While some service sectors engage in symbolic or minimal reporting, information technology and finance sectors show accelerated disclosure growth in recent years, suggesting that biodiversity awareness is expanding beyond traditional operational boundaries through reputational concerns and investor expectations. Temporal analysis reveals that disclosure evolution follows differentiated trajectories reflecting sector-specific regulatory pressures, competitive dynamics, and stakeholder configurations rather than uniform adoption patterns. Market concentration analysis demonstrates that sectoral size does not correlate consistently with disclosure leadership, indicating that targeted regulatory attention and sector-specific characteristics exert stronger influence than scale effects.

These findings make three distinct contributions to the corporate sustainability disclosure literature. First, the study provides systematic empirical evidence of sectoral heterogeneity in biodiversity reporting within an emerging market context, documenting substantial variation that existing theoretical frameworks have not adequately addressed. Second, the research identifies temporal evolution patterns that reveal how different sectors respond to institutional pressures over extended periods, challenging assumptions about linear diffusion of disclosure practices. Third, the analysis offers actionable insights for differentiated regulatory design, demonstrating that uniform policy approaches may prove inefficient when sectoral characteristics fundamentally shape disclosure capacity and stakeholder expectations. For policymakers, investors, and sustainability advocates, these findings underscore the need for regulatory frameworks that account for sector-specific characteristics while maintaining coherent standards for transparency and accountability.

2 | Literature Review

2.1 | Theoretical Lenses for CBD

CBD is based on several theories in literature. The first one is stakeholder theory. Companies must use their scarce resources effectively and efficiently to ensure their long-term survival and successfully maintain their mutual relationships with the society in which they operate. Nevertheless, in a dynamic environment where environmental factors, production, information, and communication technologies are rapidly changing, globalization has eroded traditional boundaries, and change and uncertainty are escalating, it is evident that companies cannot sustain their existence in the long term with this awareness solely (Arslantaş and Afacan Fındıklı 2013). Therefore, technical interdependence between companies and their environments is not sufficient for sustainability. In addition, social and cultural interdependence has also gained great importance for sustainability. Based on this view, it can be observed that companies are no longer structures that provide goods and services to meet the needs of society but are beginning to be defined as "systems with multiple participants and stakeholders, each of whom receives compensation for their contributions to company activities" (Donaldson and Preston 1995). Companies have now begun to act with the awareness that they should enhance their relationships with society rather than being independent of it and focus on stakeholders rather than just aiming to make a profit.

The Stanford Institute defined stakeholders in 1963 as groups without whose support a company could not survive (Mitchell et al. 1997). In Freeman's seminal book *Strategic Management: A Stakeholder Approach*, stakeholders are groups or individuals who are affected by or affect the success of the company (Freeman 1984). Freeman broadened the traditional view, which was limited to company shareholders and defined stakeholders as governments, political groups, financial and trade associations, consumers, employees, suppliers, consumer protection associations, and rival companies. In a narrow sense, stakeholders are groups that provide direct economic benefits to the company, while in a broad sense, they are groups that are affected by or affect company activities (Mitchell et al. 1997).

The concept of "stake," which constitutes the foundation of stakeholder theory, corresponds to benefit, advantage, and expectation. This benefit may be a small advantage, but it also encompasses different values, such as legal rights such as ownership (Schnietz and Epstein 2005).

The stakeholder theory is based on the understanding that interests must be aligned. In this context, there are two methods for a company to satisfy its stakeholders, who want to see their own expectations met in addition to the company's various goals being achieved (Carroll 1991): The first method is to support the stakeholder group financially, such as by allocating dividends to shareholders, offering wage increases to employees, and providing good financial value to customers. The second method involves making various decisions to help stakeholders or protect them from harm.

The primary responsibility of company managers is to meet the financial expectations of shareholders as well as the expectations of other stakeholders and to balance the expectations of all stakeholders (Donaldson and Preston 1995). Stakeholder theory states that managers should focus on increasing the welfare of all stakeholders without prioritizing any particular stakeholder's expectations in order to increase shareholder welfare (Kacperczyk 2009). In other words, a company is a joint venture established by all stakeholders, including shareholders. Siebens (2002) states that boards of directors have shifted from the understanding of serving the interests of shareholders in the best possible way to the understanding of meeting the interests and needs of all stakeholders. Baums and Scott (2005) explain that shareholders do not have sole control over companies' decision-making mechanisms; employees, customers, and suppliers also have a say. Therefore, decisions of companies are also influenced by the competitive conditions of the markets in which they operate and the social and cultural norms of the communities in which they operate.

According to the main idea underlying stakeholder theory, a company is responsible not only to its shareholders but also to its stakeholders, which include employees, customers, local communities, suppliers, the government, and NGOs. Accordingly, when determining a company's legitimacy, sustainability, and long-term value, it is expected to take stakeholder expectations into account. Biodiversity loss is a global crisis, just like climate change. Therefore, investors in companies expect them to disclose their impact on nature. Regulators also require companies to report and disclose their biodiversity risks under TNFD frameworks. Similarly, local communities also expect and demand transparency because companies directly affect their use of natural resources. In addition, customers prefer environmentally friendly companies. Considering all these factors, it is evident that CBD reflects stakeholder pressure. According to the research, stakeholder expectations are a determinant of environmental disclosures. According to Buhr (2002), reports such as the CBD are a tool for managing the expectations and demands of stakeholder groups. According to the research, the CBD is seen as a "response mechanism" from the perspective of stakeholder theory.

Another theory is institutionalization theory. The authors who made fundamental contributions to the development of Institutionalization Theory are DiMaggio and Powell (1983). However, DiMaggio and Powell (1983) made significant advances in the theory in their groundbreaking work titled "The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields." The authors (1983) investigate the reasons behind the increasing homogeneity of organizations. Revisiting Weber's (1968) concept of the "iron cage," they propose that the modern drivers of rationalization and bureaucratic order are no longer primarily market mechanisms but rather state regulations and professional pressures. As organizational fields develop, managers deliberately design their organizations to resemble others, considering this a sensible way to gain legitimacy and achieve organizational change (DiMaggio and Powell 1983).

According to institutional theory, organizations operating within a specific institutional environment must conform to the values of that environment out of a concern for legitimacy rather than for the sake of effectiveness and efficiency. Legitimacy is expressed as social acceptance based on the norms and expectations within institutional mechanisms (Deephouse and Carter 2005). In this way, organizational legitimacy is a kind of cultural support provided to the organization within the social environment. In other words, organizational legitimacy is the general perception and assumption regarding the appropriateness and acceptability of an organization's activities within a system of socially constructed norms, values, beliefs, and definitions (Suchman 1995). Organizations that achieve greater organizational legitimacy in a given institutional environment find more room to survive in that environment than others.

According to this theory, there is a process of homogenization, referred to as institutional isomorphism, which emerges in a given institutional environment based on organizational legitimacy. This process occurs through three mechanisms. These are three types of isomorphism: coercive, mimetic, and normative (DiMaggio and Powell 1983). Coercive isomorphism stems from formal or informal pressures imposed by other organizations to which the organization is dependent or by cultural expectations within the society in which it operates. The origins of this isomorphism also include political pressures and concerns about legitimization. Mimetic isomorphism stems from standard responses to uncertainty in the environment. Normative isomorphism arises from professionalization and thus the spread of certain occupational groups' norms within organizations through their establishment. Accordingly, professionals working in different organizations and influencing corporate practices share similarities in various aspects, ensuring the homogeneity of companies.

In brief terms, institutionalization refers to an application gaining legitimacy and being naturally accepted within an organization. It describes how organizational behaviors initially adopted due to various pressures gradually become "institutional norms." Practices and reporting within organizations thus become standardized. In line with this, CBD is initially often carried out due to external pressures from investors, regulations, and NGOs. Over time, this becomes routine and environmental disclosures become regular. In this way, CBD becomes part of the company's identity, not just a public relations exercise. Based

on this, it is clear that CBD has become part of the institutionalization process.

Finally, it has emerged that resource dependency theory is fundamental. Resource dependence theory argues that organizations cannot exist as fully independent or self-sufficient units. Instead, they act as social entities that rely on their external environment for survival and continuity (Biermann and Harsch 2016). From this perspective, the main idea is that organizations need to obtain vital and limited resources from outside so as to operate. The ability to access such resources shapes the balance of power among organizations. When the required resources are controlled by other actors, dependency emerges. In other words, those who hold resources gain influence and authority. The level of dependence rises with the scarcity and strategic value of resources. Actors who control these resources may then use this position to exercise political or strategic dominance over organizations. Thus, power is determined by the extent of monopoly over resources and the presence or absence of alternatives (Casciaro and Piskorski 2005).

According to theory, organizations must secure elements such as capital, natural resources, technology, and legitimacy from the external environment with a view to maintaining their continuity. Because these resources are scarce and competitive, companies develop various strategies to manage their dependencies. The aim here is to secure their resource supply and reduce uncertainties with external stakeholders.

According to research conducted by Hillman et al. (2009), companies' disclosures can be seen as a strategy for accessing critical resources. When biodiversity is accounted for, elements such as soil, water, and raw materials are directly dependent on biodiversity. Companies are subject to certain regulations in accessing these resources. Therefore, disclosing biodiversity secures the resource supply chain. This is because ESG-focused investors request biodiversity disclosure reports. In response, companies also submit CBD reports. On the other hand, this disclosure also builds trust among the public and customers, enabling the company to maintain its market share. In conclusion, CBD is a "dependency management strategy" within the framework of the resource dependency theory.

2.2 | CBD in China

Biodiversity refers to the variety of living organisms at genetic, species, and ecosystem levels, together with the ecological systems they compose in terrestrial and aquatic environments, and the processes that regulate and maintain this diversity (Waldman and Shevah 2000).

Biodiversity and biodiversity loss are addressed not only in terms of companies' responsibility to protect the environment but also as an integral part of performance, risk, and opportunity management. This is because factors arising from company activities, such as nitrogen pollution or climate change, directly lead to biodiversity loss. These losses weaken ecosystem services. In this case, food, water, raw materials, and energy supply are put at risk. Therefore, biodiversity loss threatens companies' operational sustainability, long-term profitability, and stakeholder relationships. For this reason, reporting practices such as CBD are gaining importance in the business world as both an environmental sustainability strategy and a corporate risk management tool (Zhao and Li 2022; Hald-Mortensen 2023; Zhou et al. 2025).

CBD refers to the process by which companies transparently report their impacts, risks, dependencies, and strategies related to biodiversity. CBD is a subdimension of corporate sustainability reporting. CBD is generally considered a subdimension of corporate sustainability reporting and is typically addressed within the environmental pillar of sustainability disclosures (Bouten et al. 2011). In other words, CBD is a corporate reporting practice that enables companies to systematically explain their interactions with nature, their risks, and their contributions, and has become a critical component of sustainability reporting.

Biodiversity disclosures have developed significantly over the past 20 years. At the beginning of the 2000s, reports on this subject were rare (Jones and Solomon 2013), and disclosures were generally voluntary and fragmented (Boiral 2013). By the mid-2000s, with the institutionalization of GRI standards, biodiversity had become an important dimension of corporate sustainability performance. However, the rate of adoption across sectors has varied (GRI 2016; Skouloudis et al. 2009; Rimmel and Jonäll 2013). In the 2010s, regulatory pressures and changes in the risk perception of financial institutions brought biodiversity to the fore as a financial risk factor, beyond its status as an environmental issue (Kotsantonis et al. 2016). In the 2020s, initiatives such as TNFD (2023) and ISSB (IFRS 2023) have transformed the issue from voluntary reporting to a risk-based and regulated obligation. In this way, biodiversity has taken center stage in long-term valuation and risk management processes as an integral part of ESG performance (Van Liempd and Busch 2022).

In the Chinese context, however, CBD reflects these global developments while also exhibiting unique characteristics. In the early 2000s, biodiversity disclosures in China were minimal because there were no reporting requirements. Companies saw little incentive to report (Liu and Anbumozhi 2009). However, policy interventions gradually changed this situation. In the late 2000s, guidelines from China's Ministry of Environmental Protection, along with the introduction of stock exchange rules requiring ESG disclosures for publicly traded companies, incorporated biodiversity into corporate reporting (Xu et al. 2015). Furthermore, China's hosting of the Kunming COP15 conference in 2021 brought biodiversity to the forefront of national policy discussions. This motivated companies to align their reporting with international biodiversity goals (Zhang et al. 2022).

The development in the disclosure of biodiversity information between 2001 and 2023 reflects both global institutional expansion and local political economy dynamics. Globally, biodiversity has evolved from a marginal sustainability issue to a dimension of mainstream ESG disclosures. In China, this evolution has been accelerated by state influence, international scrutiny, and the commitment of the government to ecological civilization. However, despite these advances, sectoral heterogeneity persists, demonstrating that global frameworks

alone are insufficient to eliminate sector-specific reporting differences.

2.3 | Sectoral Heterogeneity in CBD in China

One of the most prominent findings in the literature on environmental reporting is the heterogeneity observed across sectors. Resource-intensive sectors such as mining, energy, and construction provide more detailed reports on issues such as habitat restoration and species conservation due to their direct ecological impacts (Clarkson et al. 2008; Dong et al. 2014), while low-impact sectors such as finance, IT, and consulting carry out their reporting in a more symbolic manner and through partnerships (Buhr 2002; Rimmel and Jonäll 2013; Cormier and Magnan 2015). Stakeholder pressures and regulatory frameworks also increase this differentiation (Mitchell et al. 1997; Tilt 2007; Bebbington et al. 2008), while international financial principles and sectoral certifications institutionalize reporting in certain areas (Scholtens and Dam 2007; Cashore et al. 2004).

Recent research shows that the risks sectors focus on vary; the energy and chemical sectors highlight emissions and water use, while the food sector highlights supply chain-related risks (Gallego-Álvarez and Ortas 2017).

Data from publicly traded companies in China shows that biodiversity disclosures vary significantly across sectors. These differences are found to stem from factors such as exposure to ecological risks, ownership structures, and corporate pressures. Resource-intensive sectors such as mining, energy, and heavy manufacturing are sectors where the ecological consequences of their activities are visible. Furthermore, they provide more detailed biodiversity information because they are closely monitored by regulatory agencies and civil society (Dong et al. 2014; Zhang et al. 2022). These companies often disclose site-specific data such as proximity to protected areas, habitat restoration efforts, and biodiversity offsetting projects to address legitimacy concerns and maintain their operating licenses (Marquis and Qian 2014). In contrast, companies in low-impact sectors such as finance, information technology, and business services generally view biodiversity disclosures as a reputation tool and present general commitment statements or philanthropic initiatives rather than measurable ecological indicators (Buhr 2002; Xu et al. 2015). This difference highlights how sectoral significance determines the level of biodiversity reporting: Mining sectors must justify ecological impacts, while service-based companies tend to state their alignment with sustainability agendas without providing comparable depth.

Corporate and ownership factors further increase heterogeneity. Research shows that state-owned enterprises (SOEs) disclose biodiversity information more comprehensively than private companies. This is partly because SOEs are under stronger political incentives to demonstrate their support for national environmental strategies such as China's "ecological civilization" policy (Liu and Anbumozhi 2009; Li et al. 2018). Furthermore, geographical differences in the implementation of regulations also lead to inequalities: companies located in provinces with stricter environmental oversight tend to include biodiversity metrics in their reporting more than companies in less regulated regions (Zeng et al. 2010). Sectoral responses also differ depending on how biodiversity risk is framed: Energy and chemical companies emphasize habitat degradation and emissions, while agriculture and food industries focus on biodiversity risks in the supply chain, and consumer-facing companies emphasize conservation partnerships or supplier audits to meet stakeholder expectations (Gallego-Álvarez and Ortas 2017). Taken together, these patterns show that sectoral heterogeneity in China is not merely a result of industrial classification but rather an outcome of the interaction between operational impacts, corporate practices, ownership structures, and market pressures.

2.4 | Research Gaps and Study Positioning

The preceding review establishes that CBD operates within complex theoretical and empirical terrain shaped by stakeholder pressures, institutional environments, and resource dependencies. However, this literature reveals significant gaps that limit our understanding of how CBD practices develop across heterogeneous organizational contexts.

The theoretical frameworks reviewed—stakeholder theory, institutional theory, and resource dependency theory—provide complementary explanations for why firms engage in environmental disclosure. Stakeholder theory emphasizes external pressure mechanisms and legitimacy concerns. Institutional theory highlights conformity pressures and the adoption of practices that signal organizational appropriateness within institutional fields. Resource dependency theory focuses on strategic responses to environmental uncertainties and dependencies on critical resources. Yet these theories have been applied predominantly to explain within-sector variation or cross-national differences, leaving sectoral heterogeneity as a theoretical afterthought rather than a central phenomenon requiring explanation.

Empirical research on CBD in China has documented overall adoption patterns, identified ownership structure effects, and established that regulatory interventions influence disclosure behavior. Studies have shown that state-owned enterprises demonstrate higher disclosure rates than private firms, that geographic location affects reporting intensity, and that proximity to protected areas correlates with biodiversity risk recognition. However, this research typically treats sectoral membership as a control variable rather than examining how sector-specific characteristics fundamentally shape disclosure practices. The assumption that environmental exposure directly determines disclosure intensity has not been systematically tested across comprehensive sectoral classifications, nor have temporal dynamics been explored to understand whether sectors follow similar or divergent evolution pathways.

The international literature on environmental disclosure heterogeneity provides partial guidance but remains insufficient for understanding emerging market contexts. Research in developed economies demonstrates that resource-intensive sectors report more extensively than service sectors, that regulatory

frameworks create baseline disclosure requirements, and that stakeholder activism influences corporate transparency. Yet these findings emerge from contexts with mature environmental governance systems, established civil society organizations, and long-standing corporate sustainability norms. Whether these patterns hold in rapidly industrializing economies with different institutional configurations, ownership structures, and stakeholder dynamics remains an open question. China's combination of state ownership, evolving regulatory frameworks, and compressed industrialization timeline creates conditions that may produce distinct sectoral patterns not captured by existing theoretical predictions or empirical evidence from Western contexts.

Furthermore, the temporal dimension of CBD adoption across sectors has received minimal attention. While studies document increasing disclosure rates over time, the implicit assumption is that all sectors follow similar adoption curves, perhaps with temporal lags explained by regulatory timing or resource availability. This assumption overlooks the possibility that sectors may exhibit fundamentally different evolution trajectories driven by sector-specific stakeholder configurations, competitive dynamics, or materiality assessments. Understanding these trajectories is essential for designing effective policy interventions and anticipating future disclosure patterns.

Finally, policy-relevant research on differentiated regulatory approaches remains underdeveloped. Existing disclosure frameworks typically apply uniform requirements across sectors, occasionally distinguishing between listed and unlisted firms or between large and small enterprises. However, whether sectoral characteristics justify differentiated standards and how such differentiation might be structured to maintain coherence while addressing sector-specific realities has not been systematically examined. The risk is that uniform standards either set requirements too high for sectors with limited environmental exposure, creating compliance burdens without corresponding information value, or set requirements too low for environmentally intensive sectors, failing to capture material biodiversity risks.

This study addresses these gaps through comprehensive empirical analysis of sectoral heterogeneity in Chinese CBD practices over a 23-year period. By examining 19 distinct industry classifications across 57,367 firm-year observations, the research provides systematic evidence of how sectoral characteristics shape disclosure adoption, intensity, and temporal evolution. The investigation tests whether environmental exposure serves as the primary driver of sectoral differences, identifies distinct temporal trajectories that reveal differential responsiveness to institutional pressures, and develops policy-relevant insights for differentiated regulatory design. The findings contribute to theoretical development by demonstrating that sectoral heterogeneity represents a systematic phenomenon requiring explicit theoretical attention rather than a nuisance factor to be controlled. For policy and practice, the research offers evidence-based guidance for designing regulatory frameworks that account for sectoral realities while advancing overall transparency and accountability in corporate biodiversity reporting.

3 | Methodology

3.1 | Data Source and Sample Construction

This study employs a comprehensive dataset of Chinese Corporate Biodiversity Indices covering annual reports from Chinese listed companies over the period 2001 to 2023. The dataset encompasses 57,367 firm-year observations across 19 distinct industry classifications, representing one of the most extensive longitudinal examinations of CBD practices in an emerging market context. The data collection process involved systematic analysis of annual reports from Chinese publicly listed companies, with biodiversity-related content identified through comprehensive keyword recognition algorithms specifically designed for Chinese language corporate disclosures.

The selection of the 2001–2023 temporal scope reflects both substantive and methodological considerations. The period begins with China's accession to the World Trade Organization in 2001, marking the country's integration into global economic systems and the beginning of intensified international scrutiny of corporate environmental practices. The endpoint in 2023 captures the most recent complete reporting cycle available at the time of data collection, encompassing the post-Kunming COP15 period during which biodiversity gained heightened policy prominence in China. This 23-year window enables examination of long-term evolution patterns while capturing multiple phases of regulatory development, institutional transformation, and corporate awareness expansion.

3.1.1 | Regulatory Context and Disclosure Environment Evolution

The study period encompasses substantial changes in China's corporate disclosure requirements and environmental governance frameworks. These institutional shifts potentially affect the comparability of disclosure measures across time and necessitate explicit acknowledgment in the research design. This section documents major regulatory milestones and explains how the analytical approach accounts for these institutional dynamics.

The early phase of the study period (2001–2008) represents a baseline era of minimal mandatory biodiversity disclosure requirements. During this period, environmental reporting remained largely voluntary, with limited standardization or enforcement mechanisms. The 2006 Shenzhen Stock Exchange Social Responsibility Guidelines introduced preliminary expectations for listed companies to address environmental impacts, though biodiversity remained implicit rather than explicitly required. This phase establishes a reference point for measuring subsequent adoption growth driven primarily by voluntary initiative rather than regulatory mandate.

The middle phase (2009–2016) witnessed significant regulatory development. The Shanghai Stock Exchange introduced enhanced environmental disclosure guidelines in 2008, requiring listed companies in environmentally sensitive sectors to report specific environmental indicators. The Ministry of Environmental Protection issued various directives throughout

this period expanding the scope of required environmental information and establishing penalties for nondisclosure in certain high-impact industries. The 2012 revision of the Environmental Protection Law strengthened enforcement mechanisms and expanded corporate environmental responsibility definitions. These regulatory developments created heterogeneous compliance pressures across sectors, with resource-intensive industries facing more stringent requirements than service-oriented sectors.

The recent phase (2017–2023) reflects China's integration of biodiversity into mainstream ESG frameworks and policy discourse. The 2017 establishment of the Green Finance Committee created institutional infrastructure connecting environmental performance to capital market access. The announcement of China hosting the Kunming COP15 conference elevated biodiversity in national policy priorities. The 2021 conference outcomes and subsequent implementation of the Kunming-Montreal Global Biodiversity Framework intensified expectations for CBD, though formal regulatory requirements remained sector-specific rather than universal.

These regulatory shifts create potential concerns about measurement validity and temporal comparability. If disclosure increases result primarily from expanded mandatory requirements rather than genuine awareness evolution, observed patterns might reflect regulatory artifacts rather than substantive corporate behavior changes. The research design addresses this concern through several methodological approaches. First, the sectoral heterogeneity focus inherently controls for uniform regulatory pressures, as time-varying regulatory requirements affect all sectors simultaneously. Observed sectoral differences therefore reflect differential responses to common institutional environments rather than sector-specific regulatory mandates, because Chinese biodiversity disclosure regulations have not imposed substantially different requirements across sectors beyond the broad distinction between environmentally sensitive and nonsensitive industries. Second, the measurement approach captures disclosure behavior—the choice to include biodiversity-related content and the intensity of such inclusion—rather than compliance with specific reporting templates. This focus on behavioral patterns rather than checklist compliance provides insight into corporate awareness and strategic positioning independent of minimum regulatory requirements. Third, the temporal analysis examines evolution trajectories across sectors, revealing whether patterns suggest regulatory response or awareness development. Sectors demonstrating disclosure growth prior to regulatory milestones, or exhibiting continued growth beyond minimum compliance levels, provide evidence of substantive awareness evolution rather than mere regulatory conformity.

The analytical framework thus treats regulatory evolution as contextual background shaping the institutional environment within which sectoral patterns emerge, rather than as confounding factors requiring statistical control. This approach recognizes that corporate disclosure behavior inherently reflects institutional context and that sectoral heterogeneity analysis contributes to understanding how different industries navigate common regulatory landscapes through differential awareness development, stakeholder engagement, and strategic positioning.

The sample selection criteria ensure representative coverage of the Chinese equity market while maintaining data quality standards essential for longitudinal analysis. Companies were included if they filed annual reports consistently during their listing periods and provided sufficient textual content for meaningful biodiversity keyword analysis. The resulting dataset captures both large-cap enterprises and smaller listed companies, providing comprehensive sectoral representation that enables robust cross-industry comparisons.

3.2 | Variable Construction and Measurement

The analysis employs four primary measures of corporate biodiversity awareness and disclosure intensity, each capturing distinct dimensions of corporate environmental consciousness. The Biodiversity Risk variable represents a binary indicator assigned a value of one if biodiversity-related keywords appear more than twice within a company's annual report in a given year, and zero otherwise. This measure captures the threshold level of biodiversity risk recognition that indicates substantive corporate awareness rather than incidental mention. The twice-threshold criterion reflects empirical observation that single or double occurrences often represent boilerplate language or tangential references, whereas three or more occurrences typically indicate purposeful engagement with biodiversity as a material consideration.

Biodiversity Concern frequency measures are constructed as the proportion of biodiversity-related keyword frequency relative to total word frequency in annual reports, scaled by one million for interpretational clarity. The measurement process employs precise mode recognition through jieba segmentation while excluding stopwords, single-character words, and English language content to ensure accurate Chinese language analysis. The keyword dictionary encompasses terminology related to ecosystem services, species diversity, habitat conservation, natural capital, and regulatory frameworks specific to biodiversity protection, capturing both direct biodiversity references and conceptually related environmental content that indicates biodiversity awareness. This approach generates three complementary frequency measures: word-based frequency ratios, Chinese word proportion calculations, and character-based proportional analysis that collectively capture the intensity and comprehensiveness of biodiversity discourse within corporate communications.

This measurement approach aligns with established practices in corporate disclosure research while adapting to the specific context of biodiversity reporting in Chinese language documents. Recent methodological advances in biodiversity risk measurement offer alternative approaches worth acknowledging. Giglio et al. (2023) develop a sophisticated measure of corporate biodiversity risk exposure based on earnings call transcripts and systematic text analysis, capturing management attention to biodiversity-related business risks. He et al. (2024) construct biodiversity exposure indices for Chinese corporations by analyzing comprehensive textual data including annual reports, sustainability reports, and regulatory filings, employing machine learning techniques to identify biodiversity-relevant content.

These alternative methodologies capture objective biodiversity risk exposure—the degree to which firms face operational, financial, or reputational risks stemming from biodiversity dependencies or impacts. Such measures provide valuable insights into which firms are fundamentally exposed to biodiversity-related risks regardless of their disclosure choices. However, this study's research questions focus on disclosure behavior itself—the extent to which firms choose to communicate biodiversity considerations in their annual reports and how this disclosure behavior varies across sectors and over time. The keyword frequency approach directly measures this disclosure phenomenon rather than inferring underlying exposure.

This measurement choice involves explicit trade-offs. The keyword approach captures surface-level reporting behavior and may not distinguish between substantive disclosure and symbolic communication. Firms may include biodiversity-related language without corresponding meaningful action or risk management integration. Conversely, firms with genuine biodiversity exposure may choose minimal disclosure for strategic or competitive reasons. However, for research questions examining sectoral heterogeneity in disclosure practices and temporal evolution of reporting behavior, capturing what firms actually communicate provides appropriate construct validity. The analysis examines revealed disclosure preferences across sectors rather than attempting to measure underlying biodiversity risk exposure that firms may or may not choose to disclose.

Furthermore, the annual report focus reflects the specific institutional context of Chinese corporate communication. Annual reports serve as the primary mandatory disclosure vehicle for Chinese listed companies, ensuring consistent data availability across the full study period and enabling longitudinal comparison. While sustainability reports and other disclosure channels have proliferated in recent years, their adoption remains uneven across sectors and time periods, potentially introducing selection bias if included in the measurement framework. The annual report focus thus prioritizes comprehensive sectoral coverage and temporal consistency over potential information depth available through supplementary disclosure channels.

The industry classification system follows Chinese standard industrial classification codes, enabling systematic sectoral analysis while maintaining consistency with regulatory frameworks and economic policy structures. Each firm-year observation includes both broad industry category assignments and detailed subsector classifications, allowing for multiple levels of sectoral analysis depending on research question requirements. The classification system distinguishes 19 primary sectors encompassing the full range of economic activities represented in Chinese equity markets, from resource extraction through manufacturing to knowledge-intensive services.

3.3 | Sectoral Analysis Framework

The sectoral heterogeneity analysis employs a comprehensive classification approach that distinguishes between environmentally sensitive and nonenvironmentally sensitive industries based on direct environmental exposure characteristics. Environmentally sensitive sectors include agriculture, forestry, mining, water management, construction, and manufacturing industries that demonstrate direct interaction with natural ecosystems and substantial environmental impact potential. Nonenvironmentally sensitive sectors encompass finance, information technology, education, and service industries with more limited direct environmental exposure profiles.

The analytical framework examines sectoral performance through multiple dimensions including risk recognition rates, active disclosure rates, biodiversity concern intensity measures, and temporal evolution patterns. Risk recognition rates represent the percentage of firm-year observations within each sector that exceed the biodiversity risk threshold, while active disclosure rates capture the proportion of observations demonstrating any measurable biodiversity concern frequency. Biodiversity concern intensity measures provide mean, median, and maximum values for frequency-based indicators within each sector, enabling comprehensive characterization of sectoral disclosure patterns.

3.4 | Temporal Evolution Analysis

The temporal dimension of the analysis divides the 23-year study period into three distinct phases to capture evolving regulatory environments and corporate awareness development. The early period spans 2001–2008, representing the initial stages of corporate environmental disclosure development in China. The middle period covers 2009–2016, coinciding with enhanced environmental policy implementation and growing international sustainability awareness. The recent period encompasses 2017–2023, reflecting mature environmental disclosure practices and heightened biodiversity policy attention globally.

Sectoral evolution patterns are classified through growth trajectory analysis comparing adoption rates across these temporal phases. Sectors demonstrating substantial overall growth exceeding 20 percentage points combined with recent acceleration exceeding 5 percentage points are classified as exhibiting accelerating growth patterns. Steady growth classification applies to sectors showing consistent adoption increases above 10 percentage points, while moderate growth describes sectors with positive but limited trajectory development.

3.5 | Statistical Analysis Approach

The analytical methodology employs descriptive statistics, variance analysis, and cross-sectoral comparison techniques to establish sectoral heterogeneity patterns and test environmental sensitivity hypotheses. Standard deviation calculations quantify cross-sectoral variance in both adoption rates and concern intensity measures, providing objective measures of heterogeneity magnitude. Comparative analysis examines mean differences between environmentally sensitive and nonenvironmentally sensitive sector groups, establishing quantitative evidence for environmental exposure effects on biodiversity disclosure adoption.

Market concentration analysis examines the relationship between sectoral market representation and biodiversity adoption

patterns, identifying whether larger sectors demonstrate leadership effects or whether smaller sectors achieve higher adoption rates through focused regulatory attention. The analytical framework maintains consistency with established corporate disclosure literature while incorporating biodiversity-specific measurement approaches that reflect the unique characteristics of environmental risk recognition and corporate sustainability reporting practices.

This methodology enables comprehensive examination of sectoral heterogeneity while maintaining analytical rigor appropriate for policy-relevant research that addresses both academic knowledge development and practical regulatory design considerations.

4 | Results

4.1 | Sectoral Performance Distribution and Industry Rankings

The analysis reveals substantial heterogeneity in biodiversity awareness adoption across Chinese industries, with performance distributions that demonstrate clear sectoral clustering patterns. The comprehensive examination of 19 distinct industry classifications identifies 12 sectors achieving high adoption rates above 40% risk recognition, six sectors demonstrating moderate adoption between 20% and 39%, and only one sector falling below the 20% threshold.

Table 1 presents the comprehensive sectoral performance rankings, revealing Agriculture, forestry, animal husbandry and fishery as the dominant leader with 87.5% risk recognition rates across 696 firm-year observations representing 45 unique firms. This sector demonstrates exceptional biodiversity concern intensity with mean frequency scores of 1747.8 per million words and peak values reaching 17,350.4, indicating both widespread adoption and substantial disclosure depth. This finding aligns with recent cross-sectoral evidence from Sharma and Dhruv (2025), who similarly identified that sectors with high direct environmental footprints, such as energy, utilities, and agriculture, demonstrate substantially stronger reporting across direct impact indicators compared with service-oriented industries in their analysis of 47 top-revenue global companies.

Water conservancy, environment and public facilities management emerge as the second-highest performing sector with 69.1% risk recognition rates, representing the largest sample of

TABLE 1 | Sectoral biodiversity awareness performance rankings.

Rank	Industry sector	Risk recognition rate (%)	Active disclosure rate (%)	Firms	Observations	Mean concern frequency	Peak intensity
1	Agriculture, forestry, animal husbandry, fishery	87.5	94.7	45	696	1747.8	17,350.4
2	Water conservancy, environment, and public facilities	69.1	85.5	276	1100	1269.5	26,897.6
3	Scientific research and technical services	61.3	78.0	104	687	279.5	7998.4
4	Construction	55.5	72.6	100	1312	646.6	12,116.3
5	Information transmission, software, and IT services	54.0	71.5	408	4079	201.6	10,015.8
6	Mining	47.8	67.8	85	1349	439.7	15,768.4
7	Education	46.3	70.9	9	134	120.3	1298.7
8	Cultural, sports, and entertainment	45.8	65.7	61	804	139.9	1313.2
9	Finance	45.2	65.9	128	1694	142.5	2140.1
10	Transportation, warehousing, and postal services	43.4	62.6	115	1798	208.9	10,496.3
11	Leasing and business services	41.0	61.0	65	907	134.4	1891.1
12	Health and social work	40.9	59.5	16	215	140.5	2796.8

high-performing firms with 276 companies across 1100 observations. This sector achieves the highest peak biodiversity concern intensity at 26,897.6 per million words, indicating exceptional disclosure depth among leading practitioners within the sector. Hambali (2024) corroborates this pattern, demonstrating that firms operating in environmentally sensitive industries exhibit significantly higher biodiversity disclosure levels, driven by both institutional factors and corporate governance mechanisms including board size and the existence of sustainability committees.

The results demonstrate unexpected leadership from service-oriented sectors, particularly Scientific research and technical services, which achieves 61.3% risk recognition rates despite limited direct environmental exposure. These finding challenges traditional assumptions about environmental disclosure patterns and suggest that knowledge-intensive industries recognize biodiversity as material to their operational and strategic considerations. This observation resonates with findings from Bassen et al. (2025), who demonstrate that biodiversity-related disclosure quality varies not only by sector but also by how firms perceive the materiality of biodiversity risks relative to their strategic positioning, suggesting that firms in knowledge-intensive sectors may engage with biodiversity disclosure as a reputational and legitimacy-building mechanism.

4.2 | Environmental Sensitivity Analysis

The environmental sensitivity hypothesis receives strong empirical support through quantitative analysis comparing adoption patterns between environmentally exposed and nonenvironmentally exposed sectors. Table 2 presents the comparative analysis demonstrating that environmentally sensitive sectors achieve significantly higher biodiversity awareness adoption rates compared with their nonenvironmentally sensitive counterparts.

The analysis reveals a 15.9 percentage point gap in risk recognition rates between environmentally sensitive and nonenvironmentally sensitive sectors, with the former achieving 56.3% average adoption compared with 40.5% for service-oriented industries. This gap extends to active disclosure rates, where environmentally sensitive sectors demonstrate 10.1 percentage points higher engagement, and concern intensity measures, where the differential reaches 645.1 points per million words.

Environmentally sensitive sectors also exhibit greater variance in adoption patterns, with a standard deviation of 18.2 percentage points compared with 12.7 for nonenvironmentally sensitive sectors. This higher variance suggests that environmental exposure creates both opportunities for exceptional performance and risks for substantial underperformance, indicating that sectoral membership alone does not guarantee high biodiversity awareness adoption. This variance pattern is consistent with the findings of He et al. (2025), who demonstrate that the impact of firm-level biodiversity disclosure on corporate sustainability strategy is more pronounced in firms operating in non–heavy-polluting industries and those facing weaker environmental regulatory pressures, implying that environmental exposure alone is insufficient to predict disclosure behavior and that firm-level strategic considerations substantially mediate the relationship between sectoral classification and disclosure outcomes.

4.3 | Temporal Evolution Patterns

The temporal analysis reveals distinct evolution trajectories across major sectors with substantial market presence, demonstrating that biodiversity awareness adoption has followed differentiated pathways that reflect sector-specific regulatory pressures, competitive dynamics, and stakeholder expectations. Table 3 presents comprehensive temporal analysis for sectors with over 800 firm-year observations, enabling robust trend identification across the 23-year study period.

The temporal analysis identifies four sectors demonstrating accelerating growth patterns, characterized by both substantial overall growth exceeding 20 percentage points and recent momentum exceeding 5 percentage points in the 2017–2023 period (Figure 1). Information transmission, software and IT services exhibits the most dramatic evolution trajectory, advancing from 18.6% adoption in the early period to 67.8% in recent years, representing 49.2% age points of overall growth with exceptional recent momentum of 25.7 percentage points.

Manufacturing demonstrates consistent acceleration throughout the study period, achieving 28.8 percentage points of overall growth with 12.5 percentage points of recent momentum. This evolution pattern reflects increasing regulatory attention to manufacturing sector environmental impacts and growing supply chain sustainability requirements that position biodiversity as a material business consideration. This accelerating trajectory across multiple sectors corresponds to broader global

TABLE 2 | Environmental sensitivity comparative analysis.

Sector classification	Number of sectors	Average risk recognition (%)	Average active disclosure (%)	Average concern intensity	Standard deviation
Environmentally sensitive	6	56.3	74.2	812.4	18.2
Nonenvironmentally sensitive	13	40.5	64.1	167.3	12.7
Adoption gap	—	**15.9**	**10.1**	**645.1**	**5.5**

Note: Bold values indicate the higher comparative values across sector groups for each indicator, highlighting the magnitude of differences between environmentally sensitive and non-environmentally sensitive sectors in biodiversity awareness adoption.

TABLE 3 | Temporal evolution patterns by major sectors.

Industry sector	Early period (2001–2008)	Middle period (2009–2016)	Recent period (2017–2023)	Overall growth (pp)	Recent momentum (pp)	Evolution pattern
Manufacturing	12.4%	28.7%	41.2%	28.8	12.5	Accelerating growth
Information transmission, software, and IT	18.6%	42.1%	67.8%	49.2	25.7	Accelerating growth
Finance	25.3%	38.9%	52.1%	26.8	13.2	Accelerating growth
Transportation, warehousing, and postal	15.7%	31.4%	48.9%	33.2	17.5	Accelerating growth
Wholesale and retail trade	8.9%	19.2%	28.4%	19.5	9.2	Steady growth
Leasing and business services	22.1%	35.6%	44.3%	22.2	8.7	Steady growth
Real estate	11.5%	16.8%	22.7%	11.2	5.9	Moderate growth

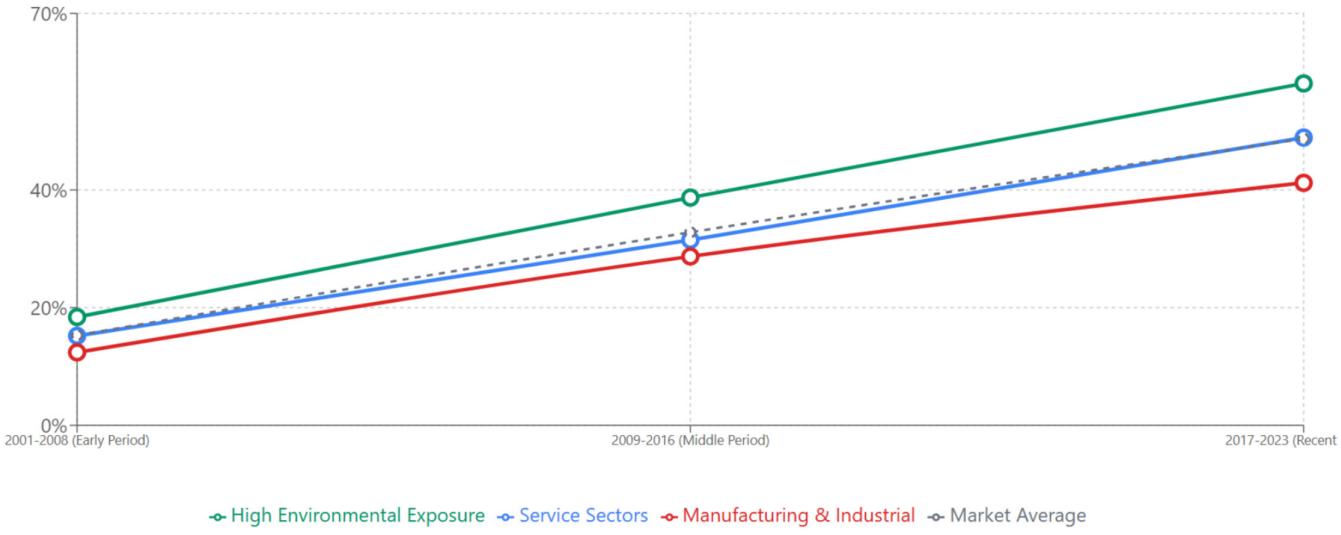

FIGURE 1 | Temporal evolution of biodiversity adoption by sector groups.

trends documented by the TNFD, which reports that over 500 companies and financial institutions have committed to TNFD-aligned nature-related reporting as of 2024, signaling a rapid institutional shift toward standardized biodiversity disclosure frameworks that increasingly permeate diverse sectoral contexts (TNFD 2024).

4.3.1 | Cross-Sectoral Variance and Market Dynamics

The comprehensive variance analysis quantifies the magnitude of sectoral heterogeneity and examines its relationship with market concentration patterns. Table 4 presents the detailed variance metrics that demonstrate substantial cross-sectoral differences in both adoption rates and disclosure intensity measures.

The analysis demonstrates high sectoral heterogeneity with a standard deviation of 16.2 percentage points in risk recognition rates, indicating that sectoral membership substantially influences biodiversity awareness adoption patterns. Biodiversity concern intensity exhibits even greater variance with standard deviations of 447.3 per million words, demonstrating that sectoral differences extend beyond basic adoption to encompass the depth and comprehensiveness of biodiversity integration within corporate disclosure practices.

The coefficient of variation analysis reveals that concern intensity demonstrates higher relative variability than risk recognition rates, suggesting that while most sectors achieve basic biodiversity awareness, the translation of this awareness into substantive disclosure practices varies dramatically across industries. This pattern indicates opportunities for targeted policy

interventions that focus on disclosure quality enhancement rather than basic adoption promotion.

4.4 | Market Concentration and Leadership Effects

The examination of market concentration patterns reveals complex relationships between sectoral size and biodiversity adoption performance that challenge assumptions about scale effects in environmental disclosure practices. Table 5 presents the analysis of market representation and corresponding adoption performance across major sectors.

The analysis reveals that market concentration does not correlate positively with biodiversity adoption performance, with several large sectors demonstrating below-average performance while smaller, specialized sectors achieve exceptional adoption rates. Manufacturing represents 35.2% of total observations but achieves only 32.1% risk recognition rates, falling below the overall market average of 45.5%.

Information transmission, software, and IT services demonstrate performance leadership effects, achieving 54.0% adoption rates despite representing only 7.1% of market observations. This pattern suggests that sector-specific characteristics, including regulatory requirements, stakeholder expectations, and competitive dynamics, exert stronger influence on adoption patterns than market size or concentration effects. This finding is further supported by evidence from Flammer et al. (2025), who demonstrate that biodiversity-related financial instruments and disclosure practices are increasingly shaped by sector-specific risk characteristics rather than firm size.

TABLE 4 | Cross-sectoral variance analysis.

Variance metric	Value	Interpretation
Risk recognition rate standard deviation	16.2 percentage points	High heterogeneity
Biodiversity Concern intensity standard deviation	447.3 per million words	Very high heterogeneity
Coefficient of variation—risk recognition	0.36	Moderate relative variability
Coefficient of variation—concern intensity	1.31	High relative variability
Range—risk recognition rates	69.0 percentage points	Substantial spread
Range—concern intensity	1627.5 per million words	Exceptional spread

4.4.1 | Policy Intervention Priority Analysis

Comprehensive sectoral analysis enables the construction of a policy intervention priority matrix that identifies sectors with the greatest potential for targeted regulatory attention and support mechanisms. Table 6 presents the strategic framework for prioritizing sectoral interventions based on current performance levels, growth trajectories, and market significance.

High priority sectors encompass manufacturing, real estate, and wholesale and retail trade, which combine substantial market representation with moderate biodiversity adoption performance. These sectors represent 75.4% of total market observations but achieve adoption rates ranging from 23.8% to 32.1%, significantly below the overall market average. The substantial market presence of these sectors creates systemic risk considerations that justify intensive policy attention and resource allocation.

Medium priority sectors include transportation, finance, and leasing services, which demonstrate near-average performance with clear growth trajectories that suggest responsiveness to policy interventions. These sectors require targeted support through best practice dissemination and peer learning mechanisms that leverage their existing adoption foundations to accelerate comprehensive implementation.

TABLE 5 | Market concentration and biodiversity adoption analysis.

Industry sector	Market share (%)	Risk recognition rate (%)	Relative performance	Leadership effect
Manufacturing	35.2	32.1	Below average	Scale constraint
Information transmission, software, and IT	7.1	54.0	Above average	Performance leadership
Finance	3.0	45.2	Average	Moderate leadership
Transportation, warehousing, and postal	3.1	43.4	Below average	Size-performance gap
Real estate	25.4	23.8	Below average	Scale constraint
Wholesale and retail trade	14.8	24.7	Below average	Scale constraint
Construction	2.3	55.5	Above average	Performance leadership

TABLE 6 | Policy intervention priority matrix.

Priority level	Sectors	Current adoption range	Intervention rationale	Recommended approach
High priority	Manufacturing, real estate, wholesale and retail	23.8%–32.1%	Large market share, moderate performance	Regulatory enhancement, incentive programs
Medium priority	Transportation, finance, leasing services	41.0%–45.2%	Near-average performance, growth potential	Best practice dissemination, peer learning
Monitoring focus	Information transmission, construction, scientific research	54.0%–61.3%	High performance, leadership potential	Benchmark development, recognition programs
Specialized attention	Agriculture, water management, mining	47.8%–87.5%	Environmental exposure, variable performance	Sector-specific regulatory frameworks

The results demonstrate that sectoral heterogeneity in Chinese corporate biodiversity awareness represents a systematic pattern driven by environmental exposure, regulatory frameworks, and competitive dynamics rather than random variation across industries. The substantial performance gaps and differentiated temporal evolution patterns create clear opportunities for targeted policy interventions that account for sector-specific characteristics and constraints.

5 | Discussion

5.1 | Empirical Findings and Theoretical Implications

The results of this study document substantial variation in biodiversity disclosure practices across sectors, revealing patterns that both confirm and challenge theoretical predictions about corporate environmental reporting behavior. The empirical evidence supports the fundamental premise that sectoral characteristics systematically shape disclosure practices, while simultaneously demonstrating that the relationship between environmental exposure and disclosure intensity operates through more complex mechanisms than simplified linear models suggest.

Firms operating in industries with direct environmental exposure report biodiversity information more extensively than service-oriented sectors, confirming predictions from stakeholder theory and institutional theory. Agriculture, mining, construction, and water management sectors achieve risk recognition rates exceeding 50%, substantially above the overall market average of 45%. This pattern reflects the operational realities of these industries, where biodiversity impacts are visible, measurable, and subject to regulatory oversight. The elevated disclosure intensity in these sectors—demonstrated through both higher adoption rates and greater keyword frequency measures—indicates that environmental exposure creates multiple disclosure pressures simultaneously. Regulatory agencies monitor these industries more closely, requiring documentation of environmental impacts and mitigation measures. Local communities affected by resource extraction or habitat modification demand transparency about ecological consequences. Investors increasingly evaluate environmental risks as material factors affecting long-term operational viability, particularly for industries dependent on natural resources or facing potential regulatory restrictions related to biodiversity protection. These findings are corroborated by recent empirical evidence from Sharma and Dhruv (2025), who observe that energy and utilities sectors, characterized by high direct environmental footprints, demonstrate stronger biodiversity reporting across several direct impact indicators compared with sectors with indirect ecological linkages. Similarly, Bassen et al. (2025) find that investors value biodiversity-related disclosure quality particularly for firms operating in impact-risk sectors, with improved disclosure associated with measurably lower cost of equity capital, suggesting that stakeholder pressure operates through tangible financial mechanisms in environmentally exposed industries.

However, the results challenge simplistic environmental determinism by revealing substantial heterogeneity within environmentally exposed sectors and unexpected leadership from industries with limited direct ecological impact. Water management demonstrates the highest peak disclosure intensity despite not achieving the highest overall adoption rates, suggesting that within-sector variation may be as important as cross-sector differences. Some mining companies provide minimal biodiversity disclosure despite operating in ecologically sensitive locations, while others develop comprehensive reporting frameworks documenting species monitoring, habitat restoration efforts, and biodiversity offsetting initiatives. This within-sector variation indicates that environmental exposure creates disclosure pressure but does not determine disclosure responses. Firm-specific factors including ownership structure, management philosophy, stakeholder engagement approaches, and competitive positioning mediate the translation of environmental exposure into disclosure behavior.

The unexpected disclosure leadership demonstrated by information technology and finance sectors represents a particularly important finding that requires theoretical explanation. These industries achieved adoption rates exceeding 50% despite minimal direct environmental impact, contradicting predictions that environmental exposure drives disclosure intensity. Several theoretical mechanisms may explain this pattern. From a stakeholder theory perspective, these sectors face distinct stakeholder configurations emphasizing reputational concerns and ethical

positioning. Technology firms increasingly confront scrutiny about their broader societal impacts beyond traditional environmental footprints, creating pressure to demonstrate awareness of emerging environmental issues including biodiversity. Financial institutions face investor expectations about environmental risk integration in lending and investment decisions, particularly as biodiversity-related financial risks gain prominence through frameworks such as the TNFD.

Institutional theory provides complementary explanation emphasizing mimetic isomorphism and professional norms. As biodiversity disclosure becomes institutionalized as a component of comprehensive ESG reporting, firms in highly visible sectors may adopt such practices to signal organizational modernity and alignment with international sustainability standards. Information technology and finance represent globally connected sectors with substantial international operations and capital market dependencies. These sectors may demonstrate particular sensitivity to international norm diffusion, adopting disclosure practices aligned with global sustainability frameworks even when domestic regulatory requirements remain limited. The finding that these sectors demonstrate accelerating disclosure growth in recent years, coinciding with increased international attention to biodiversity following the Kunming COP15 conference, supports this interpretation.

Resource dependency theory offers a third explanatory lens emphasizing strategic positioning and resource access. For knowledge-intensive sectors, legitimacy and reputation constitute critical intangible resources affecting talent recruitment, customer relationships, and regulatory goodwill. Biodiversity disclosure may serve as a symbolic investment in legitimacy capital, demonstrating organizational awareness of environmental priorities without requiring substantial operational transformation. This strategic use of disclosure as a legitimacy management tool differs from disclosure in environmentally exposed sectors, where reporting serves primarily to document material risks and demonstrate risk management capacity. This interpretation receives empirical support from Azizi et al. (2025), who examine biodiversity disclosure practices in the European financial sector and find that disclosure quality differs considerably in scope and level across financial institutions, with the evolving regulatory landscape including the EU Taxonomy, Sustainable Finance Disclosure Regulation, and Corporate Sustainability Reporting Directive serving as institutional catalysts for biodiversity engagement in the financial sector. Furthermore, He et al. (2025) demonstrate that firm-level biodiversity disclosure reduces information asymmetry and promotes green transition, with the effect being particularly pronounced in firms with lower media coverage and lower managerial myopia, characteristics commonly associated with knowledge-intensive sectors that proactively adopt transparency practices.

The temporal evolution patterns revealed through the longitudinal analysis provide additional theoretical insights about how disclosure practices diffuse across organizational fields. The finding that sectors follow differentiated evolution trajectories—some demonstrating accelerating growth, others steady adoption, and several showing moderate or stagnant patterns—challenges assumptions about uniform diffusion processes. Classic institutional theory predicts convergence as organizations within a field adopt similar practices through coercive, mimetic, and normative isomorphism. However, the persistent divergence across sectors suggests that field-level dynamics operate differently across industry boundaries. Sectors may constitute distinct organizational fields with separate institutional logics, stakeholder configurations, and legitimacy requirements, rather than participating in a unified field of Chinese listed companies subject to common institutional pressures. Recent evidence reinforces this interpretation; the TNFD 2025 Status Report indicates that 63% of surveyed respondents consider nature-related risks and opportunities more important than climate risks, while 78% have integrated nature disclosure with climate disclosure (TNFD 2025). This convergence of nature and climate reporting frameworks suggests that the accelerated disclosure trajectories observed in certain sectors may reflect the emergence of integrated environmental reporting norms that differentially penetrate organizational fields based on their existing climate reporting infrastructure and stakeholder expectations.

The differential evolution rates also reveal that disclosure practices may follow S-curve adoption patterns with sector-specific inflection points determined by regulatory attention, stakeholder mobilization, or competitive dynamics. Information technology and finance sectors show evidence of recent acceleration after sustained moderate adoption, suggesting these sectors have reached tipping points where biodiversity disclosure transitions from pioneering practice to expected norm. In contrast, manufacturing and real estate demonstrate more linear adoption patterns, indicating these sectors may be responding primarily to gradual regulatory expansion rather than experiencing rapid norm diffusion.

5.2 | Ownership Structure and Institutional Context

The role of state ownership in shaping disclosure patterns deserves particular theoretical attention. The finding that state-owned enterprises demonstrate higher biodiversity disclosure rates than private firms confirms prior research while raising questions about underlying mechanisms. State ownership may operate through multiple channels simultaneously. Political incentives align state-owned enterprises with national policy priorities, including China's ecological civilization framework that positions environmental protection as a strategic national objective. State-owned enterprise managers face performance evaluation systems that increasingly incorporate environmental criteria, creating direct incentives for demonstrating environmental awareness through disclosure. Additionally, state-owned enterprises may face lower information disclosure costs due to greater resource availability and established reporting infrastructure developed for other mandatory disclosure requirements.

However, alternative interpretations warrant consideration. The state ownership effect may reflect selection rather than causation, if state-owned enterprises operate disproportionately in environmentally exposed sectors or occupy market positions attracting greater stakeholder scrutiny. The sectoral heterogeneity analysis partially addresses this concern by examining

adoption patterns within sectors, though comprehensive disentanglement of ownership effects from sectoral characteristics would require more granular statistical analysis beyond the scope of this descriptive study.

The institutional context of Chinese corporate governance further shapes disclosure behavior in ways that may not generalize to other emerging markets or developed economies. China's combination of party-state oversight, regulatory fragmentation across ministries and regional jurisdictions, and compressed industrialization timeline creates distinctive pressures and opportunities for corporate environmental communication. The rapid evolution of environmental governance frameworks during the study period reflects the institutional experimentation and adaptive policy-making characteristic of Chinese governance approaches. Corporate disclosure behavior emerges within this dynamic institutional environment, responding to shifting regulatory signals, evolving stakeholder expectations, and changing competitive norms.

5.3 | Policy Design Implications and Regulatory Differentiation

The substantial sectoral heterogeneity documented in this study carries important implications for regulatory design and policy implementation. Current approaches to biodiversity disclosure regulation typically apply uniform standards across industries, distinguishing only between mandatory disclosure for listed companies and voluntary reporting for private firms. This uniformity reflects administrative simplicity and coherence concerns, as differentiated standards create complexity in implementation and potential ambiguity about compliance expectations.

However, the empirical evidence suggests that uniform standards may prove inefficient when sectors differ fundamentally in environmental exposure, disclosure capacity, and stakeholder expectations. For sectors with direct ecological impact and high current adoption rates—such as agriculture, mining, and water management—uniform standards may set requirements below current voluntary practice levels among leading firms. In such contexts, regulation serves primarily to establish minimum thresholds for lagging performers rather than pushing sector-wide improvement. Policy interventions might focus on mandating specific content areas, requiring quantitative metrics beyond qualitative statements, or establishing verification requirements to enhance disclosure credibility.

Conversely, for service-oriented sectors with limited environmental exposure, uniform standards may impose compliance burdens without corresponding information value for stakeholders. Requiring detailed biodiversity impact assessments from consulting firms or software companies may generate symbolic disclosures lacking substantive content, consuming organizational resources while providing minimal decision-useful information for investors or regulators. For these sectors, regulatory approaches might emphasize materiality-based disclosure, requiring firms to address biodiversity only when specific dependencies or impacts are identified through risk assessment processes.

The sectors demonstrating moderate adoption rates and market significance—particularly manufacturing, real estate, and wholesale trade—represent priority targets for policy intervention. These industries combine substantial environmental impact potential with current underperformance relative to sectoral leaders. Targeted capacity-building initiatives, best practice dissemination programs, and regulatory attention to disclosure quality could yield significant adoption improvements. The policy challenge involves designing interventions that address sector-specific barriers to adoption, whether these reflect resource constraints, limited stakeholder pressure, or uncertainty about materiality assessment. In this regard, the recently released GRI 101: Biodiversity 2024 standard, which replaces GRI 304 and references the TNFD framework, provides a comprehensive sector-neutral disclosure architecture that nonetheless accommodates sector-specific materiality assessments (GRI 2024). The standard requires organizations to evaluate biodiversity-related impacts through localized assessment processes, enabling differentiated reporting depth based on sectoral exposure profiles. This development, combined with the ISSB's announced research agenda on biodiversity and ecosystems, suggests that the international regulatory architecture is moving toward the type of differentiated yet coherent framework supported by the empirical findings of this study.

The temporal evolution patterns further inform policy timing and sequencing decisions. Sectors demonstrating accelerating adoption may require minimal regulatory intervention, as competitive dynamics and stakeholder expectations are already driving disclosure expansion. Policy efforts might focus on standardization and quality enhancement rather than adoption promotion. In contrast, sectors showing stagnant adoption patterns despite environmental exposure require investigation of adoption barriers and potentially stronger regulatory mandates to overcome resistance or inattention.

5.4 | Limitations and Future Research Directions

Several limitations of this research create opportunities for future investigation. The study's descriptive analytical approach documents sectoral heterogeneity patterns but does not employ regression frameworks to identify the specific firm-level and sector-level characteristics that predict disclosure behavior within sectors. Future research could develop multilevel statistical models examining how firm size, profitability, ownership structure, board characteristics, and environmental performance interact with sector-level factors to shape disclosure decisions. Such analysis would provide a more precise understanding of the mechanisms generating observed sectoral patterns.

The measurement approach focusing on annual report keyword frequency captures disclosure behavior but does not assess disclosure quality, credibility, or correspondence with actual environmental performance. Firms may engage in symbolic disclosure without substantive biodiversity risk management integration. Future research could develop quality assessment frameworks distinguishing between comprehensive, specific disclosure providing decision-useful information and generic, boilerplate statements lacking meaningful content. Linking disclosure measures to objective biodiversity impact indicators

would enable investigation of whether disclosure corresponds to actual environmental performance or serves primarily as reputation management.

The Chinese institutional context limits direct generalizability to other emerging markets or developed economies with different governance structures, ownership patterns, and stakeholder configurations. Comparative research examining sectoral heterogeneity across countries would reveal whether observed patterns reflect universal sectoral characteristics or context-specific institutional arrangements. Such comparison would contribute to theoretical development by identifying contingency factors that moderate the relationship between sectoral characteristics and disclosure behavior.

Finally, the study examines disclosure behavior without investigating stakeholder perceptions, information use, or market reactions. Whether sectoral variation in disclosure intensity affects investor assessments, regulatory scrutiny, or public opinion remains unknown. Future research could examine how different stakeholder groups interpret and respond to biodiversity disclosure across sectors, revealing whether disclosure produces intended legitimacy effects or faces stakeholder skepticism about symbolic communication.

6 | Conclusion

6.1 | Summary of Research and Key Findings

This study examined sectoral heterogeneity in CBD among Chinese listed companies over the period 2001–2023, analyzing 57,367 firm-year observations across 19 distinct industry classifications. The investigation employed comprehensive longitudinal analysis to document biodiversity risk recognition rates, disclosure intensity measures, and temporal evolution patterns across sectors. The analysis integrated stakeholder theory, institutional theory, and resource dependency theory to explain observed heterogeneity patterns and their evolution over time.

The empirical investigation reveals four primary findings. First, substantial sectoral variation exists in both biodiversity risk recognition and disclosure intensity, with adoption rates ranging from 24% to 88% across industries. Environmentally sensitive sectors including agriculture, mining, and construction demonstrate significantly higher adoption rates and disclosure intensity compared with service-oriented industries, confirming that environmental exposure shapes disclosure behavior. Second, temporal evolution patterns differ markedly across sectors, with information technology and finance demonstrating accelerating adoption trajectories while manufacturing and real estate show steady but moderate growth patterns. These differentiated trajectories indicate that sectors respond to institutional pressures through distinct pathways rather than following uniform adoption curves. Third, market concentration does not correlate consistently with disclosure leadership, as several sectors with substantial market representation achieve below-average adoption rates while smaller specialized sectors demonstrate exceptional performance. Fourth, within-sector variance equals or exceeds cross-sector variance in several industries, suggesting that firm-specific factors interact with sectoral characteristics to shape disclosure decisions.

6.2 | Contributions to Literature and Theory

This research makes three distinct contributions to corporate sustainability disclosure literature. First, the study provides systematic empirical documentation of sectoral heterogeneity in biodiversity reporting within an emerging market context. While prior research has documented overall CBD adoption patterns or examined specific industries, this investigation offers a comprehensive cross-sectoral comparison revealing the magnitude and structure of sectoral differences. The finding that sectors differ not only in adoption rates but also in evolution trajectories and disclosure intensity patterns demonstrates that sectoral heterogeneity represents a systematic phenomenon requiring explicit theoretical attention rather than a control variable or background factor.

Second, the research challenges simplified assumptions about the relationship between environmental exposure and disclosure intensity. The unexpected leadership demonstrated by information technology and finance sectors, combined with substantial within-sector variation in environmentally exposed industries, reveals that disclosure behavior emerges from complex interactions among environmental exposure, stakeholder configurations, competitive dynamics, and institutional pressures. Theoretical frameworks emphasizing linear relationships between environmental impact and disclosure intensity require refinement to account for these complex dynamics. The findings suggest that institutional theory's emphasis on mimetic isomorphism and normative pressures may better explain disclosure adoption in service-oriented sectors, while stakeholder theory and resource dependency theory provide stronger explanatory power for environmentally exposed industries.

Third, the longitudinal analysis contributes methodological and substantive insights about disclosure evolution patterns. The identification of distinct sectoral trajectories—accelerating growth, steady adoption, and moderate development—demonstrates that disclosure practices diffuse through differentiated pathways rather than following uniform S-curves. This finding has implications for how researchers model disclosure adoption and how policymakers anticipate future development. The temporal patterns further reveal that regulatory interventions and international norm diffusion affect sectors differentially based on stakeholder configurations, competitive structures, and materiality assessments specific to each industry.

6.3 | Policy Implications and Practical Recommendations

The documented sectoral heterogeneity patterns offer actionable guidance for regulatory design and policy implementation. Current biodiversity disclosure frameworks applying uniform standards across industries may prove inefficient when sectors differ fundamentally in environmental exposure profiles, disclosure capacity, and stakeholder expectations. The evidence

supports movement toward differentiated regulatory approaches that maintain coherence while accounting for sector-specific characteristics.

For environmentally sensitive sectors demonstrating high current adoption rates, regulatory frameworks should focus on disclosure quality enhancement rather than basic adoption promotion. Mandatory requirements might emphasize quantitative metrics, site-specific information, and verification processes to ensure disclosed information provides decision-useful content for stakeholders. For service-oriented sectors with limited environmental exposure, materiality-based disclosure approaches would allow firms to address biodiversity proportionally to identified risks and dependencies rather than producing symbolic disclosures lacking substantive content.

The sectors combining moderate adoption rates with substantial market representation—particularly manufacturing, real estate, and wholesale trade—constitute priority targets for policy intervention. These industries represent 75% of market observations but achieve adoption rates significantly below market averages. Targeted capacity-building initiatives, best practice dissemination programs, and regulatory attention to these sectors could yield substantial improvements in overall market transparency. The policy challenge involves designing interventions addressing sector-specific adoption barriers, whether these reflect resource constraints, stakeholder pressure limitations, or uncertainty about biodiversity materiality.

The temporal evolution patterns inform policy timing and sequencing decisions. Sectors demonstrating accelerating adoption may require minimal regulatory intervention, as competitive dynamics already drive disclosure expansion. Policy efforts might focus on standardization and verification rather than adoption promotion. Conversely, sectors showing stagnant adoption despite environmental exposure require investigation of barriers and potentially stronger regulatory mandates to overcome organizational inattention or resistance.

For international policymakers and standard-setting bodies, the findings highlight the importance of accounting for emerging market contexts when developing biodiversity disclosure frameworks. The Chinese experience demonstrates that rapid industrialization, state ownership structures, and compressed institutional development create disclosure patterns distinct from those observed in developed economies. International frameworks such as the TNFD and ISSB guidelines require flexible implementation approaches acknowledging these contextual differences while maintaining core transparency principles.

6.4 | Future Research Directions

Several promising avenues for future research emerge from this investigation. Developing multilevel statistical models examining firm-level and sector-level determinants of disclosure decisions would provide a more precise understanding of mechanisms generating observed patterns. Investigating disclosure quality and credibility beyond simple adoption measures would reveal whether sectoral differences extend to information substance and verification rigor. Comparative research across countries would establish whether observed sectoral patterns reflect universal characteristics or context-specific institutional arrangements. Finally, examining stakeholder responses to biodiversity disclosure across sectors would reveal whether disclosure achieves intended legitimacy effects and influences resource allocation decisions.

The sectoral heterogeneity patterns documented in this study demonstrate that biodiversity disclosure in emerging markets develops through complex pathways shaped by environmental exposure, institutional pressures, ownership structures, and competitive dynamics. Understanding these patterns provides an essential foundation for designing effective regulatory frameworks and anticipating future disclosure evolution in China and comparable emerging market contexts.

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