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The tone of buyer firms' annual reports and suppliers' green innovation: The spillover effects in the supply chain

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Abstract

Grounded in signaling theory, this study explores the effect of the tone of buyer firms' annual reports on suppliers' green innovation and investigates the factors influencing such spillover effects. We use a panel data regression method to analyze 748 paired buyer–supplier firm-year observations of Chinese listed manufacturing firms from 2010 to 2020. We demonstrate that the tone of buyers' annual reports promotes suppliers' green innovation, showing a spillover effect on the supply chain. Furthermore, the signal strength and effectiveness may be affected by the signal environment. Specifically, buyers' power over suppliers (supply chain environment) and suppliers' industry competition (industry environment) positively moderate the spillover effects of green innovation. This study enriches signaling theory and contributes to the growing literature on green innovation in supply chain management and also provides significant implications for managers.

KEYWORDS
annual reports tone, Chinese manufacturing firms, green innovation, signaling theory

1 | INTRODUCTION

While manufacturing firms play a significant role in economic development, they are also responsible for growing environmental problems, such as air pollution, global warming, and resource depletion (Aftab et al., 2022; Singh et al., 2020). In addressing environmental responsibility, manufacturing firms face the critical task of striking a balance between achieving economic profits and ensuring environmental protection (Ren et al., 2021). As an important strategic tool and a new pattern of sustainable development, green innovation has been attracting increasing research and practice attention (Wang et al., 2023; Yang & Jiang, 2023).

The growing importance of green innovation has attracted attention to its drivers. An abundance of studies and practical evidence suggest that in today's markets, manufacturing firms rely extensively on their supply chain and that firms' decision making, actions, and performance are inevitably influenced by their key first-tier buyers (Chen et al., 2019; Yang, Jiang, et al., 2021). Hence, apart from institutional (e.g., institutional pressures and environmental regulations/policies), social (e.g., enhance firms' image and social status), and firm-level (e.g., ownership and environmental orientation) antecedents (e.g., Berrone et al., 2013; Chan et al., 2016; Chen et al., 2018; Darnall et al., 2010; Fontana, 2019; García-Sánchez et al., 2020; Höflinger et al., 2018; Li et al., 2022; Yang & Jiang, 2023), emerging studies show that firms' green innovation is influenced by their key buyers, primarily buyer cooperation/participation (e.g., Hofman et al., 2020; Wang, 2020), buyer knowledge transfer (e.g., Awan et al., 2021; Song et al., 2020), and information integration (e.g., Wong, 2013). However,

List of abbreviations: 2SLS, two stage least square; CNRDS, China Research Data Services Platform; CSMAR, China Stock Market and Accounting Research; IMR, Inverse Mills ratio; LM, Loughran and McDonald; MD&A, management discussions and analyses; OLS, ordinary least-squares; PT, particular transfer; R&D, research and development; ST, special treatment.

information sharing has often focused on buyers' structured and current information, and limited attention has been paid to the impact of buyers' future information in a qualitative form.

Compared to quantitative information, qualitative information takes up more pages in firms' annual reports (Liu et al., 2023). The tone of annual reports also conveys the management's views on the firm's future. This indication of the future is very important because green innovation is different from firms' general strategic decisions, as it is a long-term decision that involves many expenditures (Tang et al., 2018). Historical or current information and practices are not sufficient for firms to make decisions, and forward-oriented information, such as the tone delivered from annual reports, plays a vital role in suppliers' decision making, such as in green innovation. This idea is the motivation behind this study to explore the effect of the tone of buyers' annual reports on suppliers' green innovation.

The tone of annual reports refers to the language used in the annual reports, which is reflected in the difference between positive and negative words included in the narrative of the annual report's text (Baginski et al., 2018; Yuan et al., 2022). This may deliver managers' messages to outsiders, thus becoming a critical source of information, supplementing financial facts (Wu et al., 2021). In recent years, owing to the rapid development of computing technologies, analyzing the tone of firms' annual reports has become an emerging research area (Cao et al., 2022). The majority of research in this area focuses on how the tone of annual reports affects firm performance, for example, market value, stock market returns, and future earnings (e.g., Ertugrul et al., 2017; Jiang et al., 2019; Li, 2010; Loughran & McDonald, 2011; Schleicher & Walker, 2010). However, little is known about the tone of annual reports' spillover effects on the supply chain; even fewer studies have explored their influence on suppliers' green innovation decisions.

To address these limitations in the literature, building on signaling theory, we examine the effect of the tone of buyer firms' annual reports on suppliers' green innovation. Studies have suggested that the strength and effectiveness of signals may vary in different environments (Montiel et al., 2012; Yang, Orzes, et al., 2021). Hence, we further consider the supply chain and industry environments and explore the influence of environment-specific contingent factors. We analyze buyer–supplier dyadic data on Chinese listed manufacturing firms from 2010 to 2020 to answer two research questions.

RQ1. What is the influence of the tone of buyer firms' annual reports on their suppliers' green innovation?

RQ2. How do the contingent factors influence the relationship between the tone of buyer firms' annual reports and the suppliers' green innovation?

This study makes three significant contributions to the literature. First, it contributes to research on corporate environmental responsibility and advances research on the drivers of green innovation by providing new insights into the value relevance of buyers' annual reports, particularly textual tone. Second, it enriches the literature on signaling theory and textual tone by investigating, for the first time to our knowledge, the spillover effects of the tone of buyers' annual reports on their suppliers. By connecting with the supply chain management literature, we expand the focus of our research from the individual firm level to the supply chain level. Third, this study provides a boundary condition for the relationship between the tone of buyers' annual reports and suppliers' green innovation by considering the moderating roles of supply chain and industry environments, which confirms that the signals are affected by the environment and provides a better understanding of how implicit signals and signal environments influence firms' strategic decisions and outcomes.

The paper proceeds as follows. Section 2 provides a literature review on the textual tone of annual reports and develops the research hypotheses; Section 3 presents the research method, including sample selection and variable measurements; and Section 4 presents the empirical results and robustness tests. We present the discussion and conclusions in Section 5.

2 | LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1 | The textual tone of annual reports

Prior research suggests that, for textual information, it is important to investigate not only the information underlying the text but also how it is presented to outsiders (Bassyouny et al., 2020; Blankespoor, 2018). Hence, deeper research is required to examine the tone of textual information. Existing studies on the tone of textual information focus primarily on firms' annual reports, earnings and bankruptcy announcements, management discussions and analyses (MD&A), and corporate social responsibility reports. In this study, we focus on annual reports because they are one of the main sources of textual information and can more comprehensively and regularly reflect the firm's future operations and development (Cao et al., 2022). In addition, recent improvements in quality requirements for nonfinancial information disclosure by capital market regulatory authorities can better ensure that the management's tone in such reports is credible.

Using both positive and negative words, the tone of annual reports can offer information about a firm's past performance, current risk factors and events, and managers' expectation of developments in the future (Li, 2010; Loughran & McDonald, 2011). Utilizing more positive words indicates a good operational situation of the firm and managers' optimistic attitudes towards development. We present two firms' annual reports as samples.

> The market layout of each business segment is continuously *optimized*, the core *advantage* of … is further *consolidated*, new *breakthroughs* are made in the development of …, … *achieved* faster *growth*, … are *promoted* in an orderly manner, and … is steadily *improved*.[1]

[1]From the 2002 annual report of Shanghai Zhenhua Heavy Industries Co., Ltd, p. 8. http://www.cninfo.com.cn/new/disclosure/detail?stockCode=600320&announcementId=1216281727&orgId=gssh0600320&announcementTime=2023-03-31.

> The firm is facing *difficulties* such as … In addition, …, which have an impact on production connection and efficiency, causing significant *pressure* on the firm's overall *cost increase* and continuously *compressing* the profit space.[2]

From the tone of the text, we can infer that the first firm has been growing well and management was confident about the future. Conversely, the second firm was facing some difficult challenges, and the management held a pessimistic attitude towards the future. Therefore, the tone of annual reports can contain incremental information for outsiders in practice (Li, 2010).

In the literature, an ample body of research suggests that the tone of annual reports is usually aligned with the firm's short- and long-term performance (Bassyouny et al., 2022), such as stock market returns and movements, business risk, future earnings, and future value (e.g., del Gaudio et al., 2020; Ertugrul et al., 2017; Jiang et al., 2019; Li, 2010; Liu et al., 2023; Loughran & McDonald, 2011; Schleicher & Walker, 2010; Wisniewski & Yekini, 2015). An increasing number of studies have explored the spillover effects of peer firms' annual report tone, that is, how disclosures by other firms affect the focal firm, suggesting that the tone of other firms' annual reports may provide focal firms with rich incremental reference information. For example, Seo (2021) demonstrates that information disclosure has a peer effect; peer information disclosure leads to firms' disclosure decisions. Lin et al. (2023) argue that positive peer MD&A tones encourage firms to hold more cash. Recent studies also document a positive association between the tone of peer firms' annual reports and the capital, innovation, and real investment decisions of focal firms (e.g., Chang et al., 2023; Cho & Muslu, 2021; Durnev & Mangen, 2020; Liu et al., 2022; Yuan et al., 2022).

While most research has focused on exploring how the tone of a firm's annual reports is associated with its future prospects and spillover effects in the same industry, little attention has been paid to the spillover effects of textual information in supply chains. Although supply chains are highly interdependent, buyers are not only the main stakeholders of suppliers but also the primary source of supplier performance. Buyers' textual information disclosure is delivered to suppliers and consequently influences their decision-making (Chen et al., 2019; Chiu et al., 2019).

2.2 | The tone of buyer firms' annual reports and suppliers' green innovation

According to signaling theory, the more informed party (sender) tries to deliver information (signal) to the less informed party (receiver) to reduce information asymmetry (Spence, 1973). It is difficult for external parties to know a firm's development prospects. Beyond the formally disclosed financial information, the tone of annual reports, as valuable textual information carriers, can provide additional information that cannot be captured by quantitative financial data and can play a signaling role. As signal senders, firms transmit positive or negative signals regarding managers' expectations of the future through annual reports, impacting the perception and behavior of external signal receivers. The positive tone of a buyer firm's annual report indicates that it is satisfied with its overall financial situation in the past year and confident in its current market position and the future development of new markets (Li, 2010), with possible spillover effects on its suppliers' green innovation performance.

First, when buyer firms present a more optimistic attitude about the future, suppliers that have not cooperated before receiving positive signals would offer more favorable terms to cooperate with buyer firms, consequently leading to greater industry competition where the supplier is located. Simultaneously, to ensure a good development trend, buyer firms should improve supplier selection criteria and provide higher requirements for suppliers. Under such circumstances, to maintain cooperative relationships, existing suppliers would strive to find ways to build long-term core competitiveness. Many studies have noted that green innovation is a critical strategic tool for manufacturing firms to obtain competitive advantages because of increasing environmental pressure (Aftab et al., 2022; Geng et al., 2021). Thus, the positive signals received by supplier peer firms prompt them to increase competitive pressure to focus on green innovation.

Second, green innovation is not only costly, as firms need to allocate a considerable amount of resources, but also comes with risks, as it is often for the long term and returns cannot be realized over a short time horizon (Tang et al., 2018). Suppliers can interpret demand information based on the tone of buyers' annual reports (Xin et al., 2022). Through transmitting incremental information, positive information disclosure by buyer firms can help reduce suppliers' uncertainties about future demand and growth opportunities and help them better assess the prospects and outcomes of their innovation investments (Durnev & Mangen, 2009; Roychowdhury et al., 2019). Firms rely heavily on supply chain members to implement their strategies and plans. Especially for innovation-related strategies, such as green innovation, the role of buyers has become particularly important, as cooperation is essential to developing environmentally innovative products or services (De Marchi et al., 2022). When the buyer delivers a positive signal, it creates a favorable opportunity for suppliers to stimulate their development by cooperating with buyers on green innovation practices. Hence, the positive signals received by the suppliers improve their willingness to implement green innovation, as the information asymmetry between the buyer and supplier is reduced, along with the risks in the green-innovation decision process.

Third, buyers and suppliers are related parties with significant economic interests (Freeman, 2010). Investors increasingly incorporate information about buyers when making investment decisions about supplier firms (Cheng & Eshleman, 2014; Madsen, 2017). A more positive tone can trigger favorable impressions among investors of buyers and suppliers sharing honor, which would further influence

[2]From the 2022 annual report of China Shipbuilding Industry Company Ltd., p.10. http://www.cninfo.com.cn/new/disclosure/detail?stockCode=601989&announcementId=1217502325&orgId=9900009267&announcementTime=2023-08-10.

investors' subsequent judgments and behaviors (Wu et al., 2021). After receiving positive information, investors raise their expectations of the supply chain and allocate more capital to the buyer and the supplier, alleviating the financing constraints of the supplier's green innovation. The easing of financing constraints provides sufficient funds for suppliers to achieve a virtuous development cycle by implementing green technology improvement plans and practices (Huang et al., 2019; Tan & Zhu, 2022). Thus, the positive signals received by investors prompt suppliers to implement green innovation practices via more financial support from investors.

Based on this discussion, we expect that the positive tone of buyer firms' annual reports, acting as external signals, would facilitate their suppliers' green innovation, giving us the first hypothesis.

> **H1.** A positive tone of buyer firms' annual reports positively affects suppliers' green innovation.

2.3 | The moderating effects

Signaling theory suggests that the strength and effectiveness of signals may vary in different environments (Montiel et al., 2012; Yang, Orzes, et al., 2021). As an important aspect of firm innovation, green innovation decisions cannot be made independently of the supply chain and industry environments. In this study, we consider two key environmental factors—buyers' power over the supplier and suppliers' industry competition—and explore whether the signals sent by buyer firms are affected by these two types of environments.

2.3.1 | Supply chain environment: Buyers' power over the supplier

Power refers to the sense of dependency between two parties owing to the relative attraction of their resources and the availability of substitutes (Fan et al., 2020). Relationship management research acknowledges that powerful parties can significantly influence the beliefs, attitudes, decision-making, and practices of others (Cox, 2004; Kim, 2000).

A high degree of buyers' power indicates that the supplier has a high level of dependence on the buyer; for the buyer, then, the cost of switching to other suppliers is lower (Banerjee et al., 2007). After receiving positive signals from the buyer, the supplier becomes aware that it will suffer significantly if it loses the buyer and is more willing to shift production operations to a more sustainable way, that is, implement green innovation practices to better meet the buyer's strategic and operational objectives (Najafi-Tavani et al., 2022; Yang, Jiang, et al., 2021).

Moreover, powerful buyers can exert relative control over suppliers (Berthon et al., 2003), which not only prevents suppliers from engaging in opportunistic behavior (Zhao et al., 2008) but also enables them to implement practices that meet buyers' expectations (Liu et al., 2017). Fan et al. (2022) and Lanier et al. (2019) state that when buyers have relatively high power, they may assign some R&D work to their suppliers, thus increasing suppliers' green innovation capabilities.

By contrast, although a positive tone of the buyer firm's annual report can potentially trigger the supplier's green innovation under a low level of buyers' power, the buyer's insufficient control would not enable the supplier to engage in such high-cost and high-risk practices. In addition, buyers' insufficient power may raise opportunities for suppliers' opportunism, which can significantly reduce their commitment to the buyer–supplier relationship and develop in an unsustainable way. Therefore, we propose the second hypothesis:

> **H2.** Buyers' power strengthens the positive impact of the tone of buyer firms' annual reports on suppliers' green innovation.

2.3.2 | Industry environment: Suppliers' industry competition

The industry environment may play a role in firms' green innovation decisions (Pan et al., 2020). The effects of buyer firm annual reports' positive tone on suppliers' green innovation may expand under fierce industry competition for the following reasons.

First, by interpreting the positive tone of the buyers' annual reports, suppliers would want to continue cooperating with the buyers. Then, when the level of industry competition is high, to maintain a stable cooperation situation and avoid falling behind peer firms, suppliers have a strong motivation to carry out strategic innovation and ensure long-term competitive advantage (Mueller et al., 2021). Previous research (e.g., Cai & Li, 2018; Hu et al., 2022) argues that in the face of a complex industry competition environment, manufacturing firms would be more motivated to comply with environmental regulations and implement green innovation because, otherwise, they would face a loss of competitive advantage, reputation, and legitimacy.

Second, according to Feng et al. (2022) and Li and Zhu (2021), a high level of industry competition may improve the degree of information disclosure, which is beneficial for suppliers to exchange information and acquire new green innovation-related knowledge (Huo et al., 2021; Yang et al., 2016). Although green innovation is accompanied by high uncertainty, the accelerated speed of green technology spillover and learning effects from peer firms caused by industry competition can reduce uncertainty and improve suppliers' willingness to implement green innovation practices.

In comparison, if competition in the industry is relatively weak, suppliers are less likely to develop new projects and innovations given the high costs and risks (Ross, 2004). They may believe that the decrease in profits caused by a slight increase in competition is less than (and preferable to) the losses caused by green innovation uncertainties. Therefore, the supplier's tendency to avoid green innovation risks weakens firms' innovation motivation, even though the buyer firm shows good development prospects. Therefore, when there is

fierce competition in an industry, the role of buyer firms' positive tone becomes more important in triggering suppliers to improve their green innovation to distinguish them from their competitors. Thus, we posit the following hypothesis:

> **H3.** Suppliers' industry competition strengthens the positive impact of the tone of buyer firms' annual reports on suppliers' green innovation.

Figure 1 illustrates the overall research model.

3 | METHODOLOGY

3.1 | Data and sample

This theoretical model was tested in China. The Chinese market provides a unique opportunity to study this topic for several reasons. First, in contrast to Western countries, green innovation in China is primarily promoted by the Chinese government (Li et al., 2018). However, the knowledge of the importance of buyers' qualitative information in Chinese firms is limited. Second, Chinese culture is regarded as a high-context culture that depends on implicit communication (Hall, 1976) and is more suitable for exploring implicit information through the tone of annual reports to obtain incremental information (Wu et al., 2021). Third, due to the different social, cultural, political, and economic structures compared to the West, buyer–supplier relationship management is also distinct (Liu et al., 2008), and the findings of this research can promote investments with Chinese firms.

To obtain the buyer–supplier dyadic sample firms, we first collect data for the top five customers of the listed firms from the China Research Data Services Platform (CNRDS) database from 2010 to 2020. Considering that when the buyer firm is non-listed, it is not easy to obtain its annual report, we choose only dyadic firms that are both listed on the Chinese A-share market (Yang & Jiang, 2023). We start with 2010 because we lag green innovation performance by 1 year, which is obtained from the CNRDS database since 2011. Thus, 2,130 pairs of observations are chosen as the initial samples.

Next, we select supplier firms in the manufacturing industry. Manufacturing firms are an ideal industry setting because they face more environmental pressure than others (Huang et al., 2021) and must strive to achieve sustainable development through green innovation (Xiang et al., 2022). We exclude firm-year observations with the year labeled special treatment (ST) or particular transfer (PT) to reduce bias and observations with missing data. The final sample comprises 748 paired buyer–supplier firm-year observations. To exclude any outlier effect, we winsorize all continuous variables at 1% and 99%. Moreover, we include a 1-year lag between the dependent variable, green innovation ($t + 1$) and the explanatory variables (t) to address potential reverse causality.

3.2 | Measurements

3.2.1 | Green innovation

Consistent with previous studies (Qi et al., 2021; Wang & Jiang, 2021), we use the number of green patent applications as the indicator of suppliers' green innovation performance (*Innovation*). The total number of patent applications is selected rather than the grant year because patent applications measure a firm's innovation efforts, and the application date is closer to the actual time of innovation activities (Cumming et al., 2020; Guan et al., 2021). Considering the skewness concern, a natural logarithm of one plus the total number of applications is used in our analysis.

3.2.2 | The tone of buyer firms' annual reports

We obtained the tone data for annual reports from the CNRDS database, created based on the widely used Loughran and McDonald (2011) (LM) dictionary that presents a specialized finance wordlist with positive and negative vocabulary in English. Then, the CNRDS translates the English vocabulary into Chinese and further adjusts and improves the words by combining the Chinese context, resulting in a total of 1,076 positive words (e.g., abundant, achievement, better, and creative) and 2,080 negative words (e.g., abandon, bad, and closed). Using textual analysis software, this database captures the number of positive and negative words presented in each annual report that appear on the translated wordlist. Following most studies on this topic (e.g., Cao et al., 2022; Yuan et al., 2022), we measure tone as (the number of positive words−negative words)/the total number of words in the annual reports. A higher value represents a more positive tone in buyer firms' annual reports.

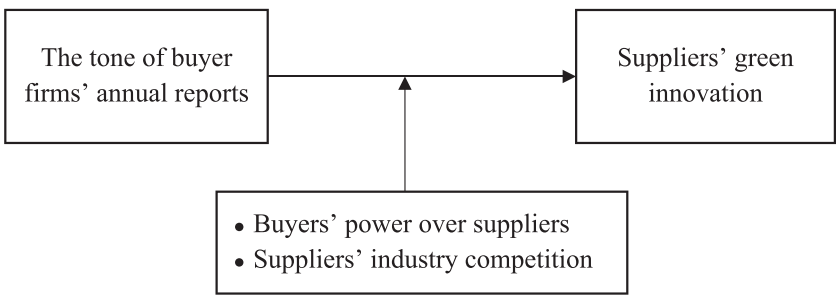

FIGURE 1 Research model

TABLE 1 Descriptive statistics and correlation

	1	2	3	4	5	6	7	8	9	10	11	12
1. Innovation	1											
2. Tone	0.094**	1										
3. Power	−0.005	0.025	1									
4. Competition	0.026	−0.015	−0.047	1								
5. Size	0.310**	−0.074*	0.067	−0.038	1							
6. Age	−0.038	−0.160**	−0.077*	0.174**	0.188**	1						
7. ROA	0.128**	0.046	0.017	0.015	−0.067	−0.172**	1					
8. Leverage	0.084*	−0.007	0.020	−0.111**	0.508**	0.153**	−0.436**	1				
9. Liquidity	−0.041	0.034	−0.013	0.125**	−0.400**	−0.213**	0.291**	−0.638**	1			
10. R&D	0.099**	0.022	−0.129**	0.146**	−0.309**	−0.132**	0.145**	−0.371**	0.392**	1		
11. Concentration	0.112**	0.070	0.095*	−0.184**	0.130**	−0.263**	0.121**	0.003	0.013	0.003	1	
12. Ownership	0.110**	0.039	0.076*	−0.140**	0.396**	0.028	−0.140**	0.438**	−0.310**	−0.169**	0.151**	1
Mean	0.823	0.002	7.104	29.334	21.961	16.130	0.039	0.428	2.587	0.032	0.349	0.440
S.D.	1.019	0.011	5.463	22.454	1.252	5.135	0.045	0.216	3.027	0.030	0.142	0.497

Note: $N = 748$ (sample size for power = 714).
*Statistical significance at the 5% level.
**Statistical significance at the 1% level.

TABLE 2 Results of the regression analysis

Variables	Model 1	Model 2	Model 3	Model 4
Tone		8.431**	10.174***	7.985**
		(3.365)	(3.693)	(3.313)
Power			0.003	
			(0.007)	
Tone*Power			0.109***	
			(0.032)	
Competition				0.014
				(0.005)
Tone*Competition				0.071**
				(0.035)
Size	0.408***	0.412***	0.414***	0.409***
	(0.048)	(0.048)	(0.049)	(0.047)
Age	0.004	0.004	0.003	0.003
	(0.010)	(0.010)	(0.011)	(0.010)
ROA	2.093***	1.995**	2.418***	2.113***
	(0.779)	(0.783)	(0.843)	(0.779)
Leverage	−0.050	−0.023	0.028	−0.039
	(0.246)	(0.247)	(0.257)	(0.241)
Liquidity	0.012	0.014	0.014	0.018
	(0.013)	(0.013)	(0.013)	(0.013)
R&D	4.231***	4.092***	4.176***	3.825***
	(1.320)	(1.305)	(1.335)	(1.312)
Concentration	0.385	0.372	0.365	0.380
	(0.283)	(0.281)	(0.283)	(0.280)
Ownership	0.006	0.000	0.009	0.025
	(0.084)	(0.084)	(0.083)	(0.083)
Constant	−7.973***	−8.093***	−8.156***	−8.487***
	(0.999)	(0.995)	(1.019)	(0.992)
Industry dummy	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes
R-squared	0.2761	0.2829	0.3039	0.2930
N	748	748	714	748

Note: Robust standard errors are shown in parentheses.
*Statistical significance at the 10% level.
**Statistical significance at the 5% level.
***Statistical significance at the 1% level.

3.2.3 | Moderators

Buyers' power

Previous studies agree that a buyer's power over a supplier is reflected in the buyer's inventory turnover (Kim & Davis, 2016; Yang, Jiang, et al., 2021). Hence, following the existing literature, we use the inventory turnover ratio as an indicator of buyers' power (*Power*), which is calculated as operating costs divided by average inventory.

Suppliers' industry competition

The Herfindahl–Hirschman Index HHI, calculated as the sum of the squared market shares of all firms in the same industry, is an indicator of industry concentration. A value close to one implies few competitors and less competitive intensity (Boyd, 1995). We use the reciprocal of the HHI to measure industry competition (*Competition*) (Wiengarten et al., 2017); a higher value indicates higher industry competition.

3.2.4 | Control variables

Following the literature on green innovation (e.g., Pan et al., 2020; Ren et al., 2021), we control for several firm-level factors. (1) Due to the higher legitimacy of larger firms participating in green innovation

(Luo et al., 2017), we control for firm size (*Size*) in the models, measured as the natural logarithm of the firm's total assets. (2) Older companies are exposed to green innovation isomorphism for longer periods of time (Slawinski & Bansal, 2015). Hence, firm age (*Age*) is included in the model as a control variable. We measure this as the number of years since the establishment of the firm. (3) A firm's financial performance is expected to affect its green innovation; therefore, we control for *ROA*. (4) Slack resources enable firms to respond more flexibly to market opportunities (Guenther & Guenther, 2020). Accordingly, we control for slack resources, as measured by financial leverage (*Leverage*, the ratio of total debt to total assets) and liquidity (*Liquidity*, the ratio of current total assets to current total liabilities) (Bhattacharya et al., 2021). (5) Previous studies show that a firm's R&D intensity (*R&D*) is positively associated with green innovation. We then control for and measure it as R&D expenses divided by total sales (Symeou et al., 2019). (6) Firms' ownership concentration (*Concentration*) may also affect their green innovation (García-Sánchez et al., 2020). Therefore, we control for it as the shareholding ratio of the largest shareholder. (7) Last, we control for a firm's ownership (*Ownership*) as a dummy variable (1 for state-owned firms and 0 otherwise). Furthermore, industry and year fixed effects were also controlled. These data are obtained from the CSMAR and Wind databases.

4 | RESULTS

4.1 | Description analyses

Descriptive statistics and correlations are presented in Table 1. The suppliers' average green innovation value is 0.823, with a standard deviation of 1.019, indicating a variation in firms' green innovation performance. The mean tone is 0.002, indicating that buyer firms' average annual report tone is positive. Consistent with our expectations, a significantly positive relationship (.094, $p < .01$) is found between *Tone* and *Innovation*. Furthermore, the correlations between these variables are less than .65. Therefore, multicollinearity is not a concern.

4.2 | Regression results

We used ordinary least-squares (OLS) regression analysis to test these hypotheses. The regression results are presented in Table 2. We regress only the control variables for green innovation in Model 1. It shows that firms with a larger size, better financial performance, and higher R&D intensity tend to have higher green innovation performance. Model 2 shows the direct effect of the buyer firm tone on supplier green innovation. As shown in Model 2, we find a strong positive relationship ($\beta = 8.431$, $p < .05$), which supports H1.

Models 3 and 4 were used to test the moderating effects by adding the interaction terms. We center the variables before constructing the interaction terms to alleviate multicollinearity concerns. We can see that the coefficients of *Tone* are all significantly positive when considering the moderating effects ($\beta = 10.174$, $p < .01$; $\beta = 7.985$, $p < .05$). More importantly, the two coefficients of the interaction terms are also positive and significant ($\beta = .109$, $p < .01$; $\beta = .071$, $p < .05$). These results indicate that buyers' power and suppliers' industry competition would strengthen the positive relationship between buyer firms' annual report tone and suppliers' green innovation. Thus, H2 and H3 are supported.

To corroborate the moderation effect, we plot the interaction effects by separating the high (one standard deviation above the average value) and low (one standard deviation below the average value) levels of the moderating variables. As shown in Figure 2a,b, the main effect is all positive. Moreover, they also show that the positive relationship between buyers' annual report tone and suppliers' green innovation is reinforced when the moderators are relatively high.

4.3 | Robustness checks

Next, we perform robustness checks to improve the reliability of the results. First, we use an alternative calculation method for buyer firms' annual report tones to replicate our analyses. Following Cao et al. (2022), we replace the measurement with (number of positive words−negative words)/(number of positive words + negative words) in annual reports. The results are presented in Models 1–3 in

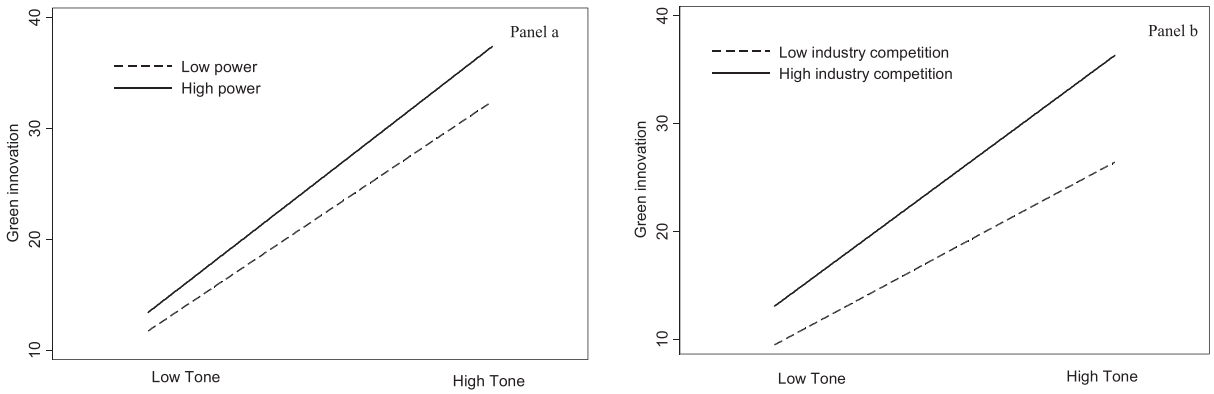

FIGURE 2 Moderating effects: (a) buyers' power over suppliers and (b) suppliers' industry competition

TABLE 3 Results of robustness analyses

Variables	Alternative measure for the tone of annual reports			Alternative regression model		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Tone	1.070**	1.266***	1.001**	14.635**	18.623**	11.788*
	(0.427)	(0.478)	(0.420)	(7.094)	(7.573)	(7.053)
Power		0.003			−0.003	
		(0.007)			(0.014)	
Tone*Power		0.105***			0.157**	
		(0.031)			(0.061)	
Competition			0.014***			0.027**
			(0.005)			(0.011)
Tone*Competition			0.076**			0.140*
			(0.035)			(0.072)
Controls and constant	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
(Pseudo) *R*-squared	0.2827	0.3035	0.2932	0.4169	0.4410	0.4261
N	748	714	748	748	714	748

Variables	Heckman two-stage model			Instrumental variable approach	
	Model 7	Model 8	Model 9	Model 10	Model 11
Industry-average tone				1.122***	
				(0.070)	
Province-average tone				0.847***	
				(0.143)	
(Predicted) tone	8.938***	10.588***	8.500**		18.227***
	(3.395)	(3.751)	(3.360)		(6.745)
Power		0.002			
		(0.007)			
Tone*Power		0.102***			
		(0.031)			
Competition			0.012***		
			(0.004)		
Tone*Competition			0.067*		
			(0.035)		
Inverse Mills ratio	−0.172	−0.135	−0.067		
	(0.753)	(0.752)	(0.760)		
Controls and constant	Yes	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes
R-squared	0.2803	0.2998	0.2899	0.4085	0.2737
N	748	714	748	748	748

Note: Robust standard errors are shown in parentheses.
*Statistical significance at the 10% level.
**Statistical significance at the 5% level.
***Statistical significance at the 1% level.

Table 3. We find that the coefficients of *Tone* and the two interaction terms are all significantly positive, consistent with previous tests.

Second, considering that the dependent variable (i.e., the number of green patents) in the models is count data, to obtain more robust results, we replace the OLS regression models with the Poisson

models in the robustness checks (Gurmu & Trivedi, 1996). The estimated results of Models 4–6 in Table 3 show that buyers' annual report tone positively affects suppliers' green innovation and the coefficients of the two interaction terms are still positive and significant. Hence, the re-estimated results obtained using the Poisson model are qualitatively similar to those reported in Table 2.

Third, it is voluntary for Chinese listed firms to disclose information on buyer firms, which may lead to sample selection bias. Hence, we designed a Heckman two-stage model to address this concern (Heckman, 1979). In the first stage, we set a dummy variable to determine whether the firm discloses buyer firms' information. Specifically, we regress the dummy variable on all the control variables defined in Section 3.2.4, using a Probit model and obtain the Inverse Mills ratio (IMR). The IMR is then included in the second-stage regression. We present the second-stage results in Models 7–9 in Table 3. As the inverse IMR is not significant, sample selection bias may not have affected our results. At the same time, the coefficients of *Tone* and the interaction terms are positive and significant, suggesting that the results are reliable.

Fourth, to address the causality between buyers' annual report tone and suppliers' green innovation performance, we use the instrumental variable method with a 2SLS estimator. Similar to previous studies (e.g., Kong et al., 2021), we use industry-average and province-average firms' annual report tones in the same year as the instrument. The regression results are presented in Models 10 (first stage) and 11 (second stage) in Table 3. The first-stage regression results show that the instrument variable's coefficient is positive and significant. The *F* value is 95.31, which is higher than the approximate cutoff of 10 for weak instruments (Stock & Yogo, 2005). The second-stage regression results show that the coefficient of the predicted *Tone* is 18.227 and significant at the 1% level, indicating that the positive relationship between buyer firms' annual report tone and suppliers' green innovation remains robust to the instrumental variable method.

5 | DISCUSSION AND CONCLUSIONS

With the growing intensity of market competition and environmental pollution, manufacturing firms need to maximize their economic interests while protecting the environment, which calls for increased attention to green innovation (Wang et al., 2023; Yang & Jiang, 2023). Scholars exploring the drivers of green innovation argue that firms' decision-making is affected by their buyers in the supply chain. However, limited attention has been paid to the effect of buyer firms' textual information, that is, the tone of their annual reports, on driving green innovation implementation. Hence, based on signaling theory, this study focuses on the impact of buyer firms' annual report tone on suppliers' green innovation and conducts an empirical test using data from Chinese listed manufacturing firms from 2010 to 2020. The findings indicate a spillover effect of buyer firms' annual report tone on green innovation in their suppliers. They also show that the spillover effects of buyers' annual report tone on suppliers' green innovation are greater under high levels of buyers' power and suppliers' industry competition. Our findings have critical theoretical and practical implications.

5.1 | Theoretical implications

First, the results provide new insights into the drivers of green innovation. Extensive research has concentrated on the role of external institutions, social factors, and firm internal characteristics on firms' green innovation (e.g., Berrone et al., 2013; Chan et al., 2016; Chen et al., 2018; Darnall et al., 2010; Fontana, 2019; García-Sánchez et al., 2020; Höflinger et al., 2018; Li et al., 2022; Yang & Jiang, 2023). Although there is an increasing body of research on buyer firms' effects (e.g., Awan et al., 2021; Song et al., 2020), they mainly focus on structured and current information on firms' strategic decisions, overlooking their unstructured and future-oriented textual information. Given that textual information can reflect management attitudes (Wu et al., 2021), our study focuses on this missing factor, showing that buyers' annual report tone has a positive effect on suppliers' green innovation. This result echoes the findings of Awan et al. (2021) and Song et al. (2020) and further offers new insights into the role of buyers in suppliers' green innovation. Meanwhile, our study enriches the emerging research area on qualitative textual information literature by extending its application to the context of firms' green innovation and supplements the consequences of narrative disclosure tone (Bassyouny et al., 2022). In addition, the results are consistent with prior findings that the tone of annual reports can provide incremental information and influence firms' decision making (Li, 2010; Loughran & McDonald, 2011; Wu et al., 2021).

Second, our research enriches signaling theory by exploring spillover effects in the supply chain. Although studies have confirmed the signaling role played by the tone of annual reports, they focus more on investors' signal receivers and analyze the effect of investors' reactions on signal senders' performance (e.g., Ertugrul et al., 2017; Jiang et al., 2019; Schleicher & Walker, 2010). A few studies have investigated the spillover effects of firms' annual report tone on peer firms (e.g., Cho & Muslu, 2021; Yuan et al., 2022). However, spillover effects on supply chain firms have received little attention. Since key buyers are important stakeholders in manufacturing firms (Yang, Jiang, et al., 2021), buyer signals have a significant potential impact, making it necessary to learn whether and how buyers' textual information affects supplier decisions. This research fills this gap by expanding the vision from the firm level to the supply chain level and is one of the first studies to investigate the spillover effects of the tone of annual reports in the supply chain. In this sense, our theoretical analysis and empirical testing of buyers' textual tone signal effects in the supply chain are important supplements to textual tone literature and signaling theory. Additionally, the verified positive effect supports the views of Hofman et al. (2020) and Yang, Jiang, et al. (2021) that firm performance is related to supply chain partners.

Third, this research extends signaling theory beyond simply answering whether buyers' annual report tone signals are related to

suppliers' green innovation and further helps us better understand when their relationship is strengthened by introducing moderators. Previous studies have focused on exploring the direct impact of the tone of annual reports on firms' performance (e.g., Ertugrul et al., 2017; Jiang et al., 2019), but few have examined the circumstances under which their relationship is more likely to be established. Our research complements these studies by theoretically explicating and empirically verifying that the signaling environment (i.e., buyers' power over the supplier and suppliers' industry competition) moderates the relationship between tone signals and suppliers' green innovation. The results confirm what Montiel et al. (2012) and Yang, Orzes, et al. (2021) suggest; that is, the strength or effectiveness of signals is affected by the environment and further determines specific environmental factors. This not only extends the understanding of how the supply chain and industry environments can influence firms' green innovation decision-making when facing the positive tone of buyers' annual reports but also highlights a novel research avenue, that is, capturing which environmental factors may affect the strength or effectiveness of signals.

5.2 | Practical implications

First, the spillover effects of annual report tone in the supply chain confirm that buyers' annual reports are important sources of information for suppliers' business strategy decisions. Hence, firms should combine buyer information with their development status when strategizing, particularly for future-oriented green innovation decisions. It is not sufficient for managers to focus solely on buyers' quantitative financial data; they also need to pay attention to their qualitative textual tone, which can provide incremental information. Specifically, managers should monitor their key buyers by carefully and regularly analyzing announcement information and avoiding strategic decision mistakes due to information asymmetry.

This is particularly true for suppliers with less power over key buyers and those in competitive industries. Suppliers with less power must depend more on buyers and act proactively to maintain competitive advantages. Additionally, suppliers facing intense industry competition must try their best to establish long-term collaborative relationships with buyers to ensure their survival. In such business scenarios, managers should realize that green innovation is a critical strategy. When buyers have a positive attitude towards the future, implementing green innovation is an effective way to improve the competitive advantage of suppliers and catch up with the positive development of buyers.

However, compared to quantitative information, qualitative information can be expressed in various ways, which creates conditions for management to manipulate the tone in annual reports (e.g., hide unfavorable news) (Huang et al., 2014). Although our study shows that buyer firms' positive annual report tone is a driver of suppliers' green innovation, it does not necessarily encourage buyers to deliberately embrace more positive language or even adopt greenwashing behaviors. Qualitative information is an important supplement to quantitative information. If the market finds that over-positive qualitative information is inconsistent with quantitative information in the future, the firm will be considered dishonest in covering up bad news, thereby reducing investors' impressions of the firm and, ultimately, increasing business risks. Moreover, an abnormal positive tone could predict negative future earnings and cash flows, which indicates greater risk (Hossain et al., 2020; Huang et al., 2014). Hence, the tone of annual reports does not need to be too positive but must reflect authenticity and credibility that investors come to depend on.

Regarding tone manipulation, suppliers should be cautious when making decisions based on the tone of buyers' annual reports and should preferably assess the buyers' actual operating conditions and development plans. Through frequent communication and improved judgment, firms can capture buyers' attitudes towards future development, which can not only verify the tone of annual reports but also supplement other implicit information. For buyer firms, it is important to use an appropriate tone to disclose authentic information to prevent adverse market reactions caused by window-dressing. In addition, because of the crucial importance of information disclosure in the capital market, relevant government offices must pay attention to firms' textual information disclosures. To prevent managers from misleading information users by manipulating textual information and to maintain a fair, transparent, and orderly market environment, governments should strengthen management and raise the quality requirements of qualitative information disclosed by firms. Firms may deliberately conceal negative information and issue misleading statements and should be punished for this.

5.3 | Limitations and future research

This study has a few limitations. First, the measure of textual information used in this study can be improved. We measured the tone of annual reports based on the number of positive and negative words, without considering the degree of positivity or negativity contained in these words. Thus, it is possible to have fewer positive words than negative words, but a stronger positive tone; in this case, it may drive suppliers' green innovation. Therefore, simply subtracting the number of words between the two categories may ignore or downplay the impact of the degree of the tone. However, the most widely used LM dictionary can only recognize words that are positive or negative, and it is difficult to identify the degree of their tone. Hence, future research can further classify the words in the LM dictionary into different degrees and construct a more comprehensive indicator based on the number as well as degree to measure textual tone.

Second, although our study examines the moderating effect of buyers' power and suppliers' industry competition, other environmental factors may also have such an effect. For example, based on the relational view, we speculate that buyer–supplier relational networks, relationship quality, or reciprocal trust in the supply chain environment may influence the buyer–supplier relationship. Future research should consider the roles of these additional factors. In addition, given that all firms conduct business in a certain institutional environment,

based on institutional theory, it is possible to consider macro-level environmental factors to understand how a country's institutions could have a moderating effect. Exploring the interactions between micro- and macro-level signal environments that may affect the signal strength would be interesting as well.

Third, we focused only on manufacturing firms and did not differentiate between firm types. Future research could further explore the spillover effect differences in different firm types, such as large and small firms, or highly polluting and other firms. Additionally, the sample concentrated on publicly listed manufacturing firms, which may have affected the generalizability of the findings. Future research could expand the sampling framework to cover a broader range of industries or examine the relationships in smaller, private businesses by conducting in-depth interviews or surveys based on buyer–supplier dyadic samples to allow for stronger conclusions.

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CONFLICT OF INTEREST

We have no conflict of interest to disclose.

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