

Corporate Sustainability Disclosure, Green Innovation, and Firm Competitiveness: The Roles of Environmental Uncertainty and Institutional Pressure

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Abstract

This study examines the impact of Corporate Sustainability Reporting Directive (CSRD) alignment on green innovation and firm competitiveness among Chinese manufacturing firms, with environmental uncertainty and institutional pressure as the moderating variables. Grounded in institutional theory, the study analyzes how institutional pressure and environmental uncertainty condition the translation of sustainability reporting into environmental innovation. In this study, we collected data from 320 senior managers, sustainability officers, and R&D managers across three Chinese provinces using a structured questionnaire. Using partial least squares structural equation modeling, the results reveal that CSRD alignment significantly enhances both green innovation and firm competitiveness. Green innovation partially mediates the relationship between CSRD alignment and competitiveness, confirming its role as a strategic pathway to competitive advantage. In terms of moderation, environmental uncertainty weakens the positive effect of CSRD alignment on green innovation, whereas institutional pressure does not significantly moderate this relationship. These findings extend institutional theory by demonstrating how sustainability directives drive innovation-based competitive advantage through contingent mechanisms. Practically, the study offers managers strategic insights into leveraging sustainability reporting to strengthen environmental performance and competitive positioning amid market uncertainty.

Keywords: *CSRD alignment, green innovation, environmental uncertainty, institutional pressure, firm competitiveness*

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1. INTRODUCTION

As China promotes high-quality, sustainable development, the Chinese manufacturing sector is under growing pressure to intensify its environmental and social responsibilities. Among recent regulatory developments, the European Union's Corporate Sustainability Reporting Directive (CSRD) stands out: it took the place of the Non-Financial Reporting Directive (NFRD) and brought a far larger population of firms under a common set of sustainability disclosure rules (European Parliament and Council, 2022). What sets the CSRD apart is its double materiality logic, whereby a company has to report in two directions at once—how sustainability issues bear on its own financial prospects, and how its activities bear on society and the natural environment (Mezzanotte, 2023). Leal Filho et al. (2025) show that companies' preparedness to comply with the European Sustainability Reporting Standards (ESRS) varies considerably, with larger firms

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better aligned than smaller ones. Following legislative developments by the Chinese government, including the Environmental Protection Law and Green Development Guidelines, as well as its commitment to achieving carbon neutrality by 2060, industrial enterprises have increasingly aligned their disclosure practices with international sustainability reporting frameworks such as the ESRS and CSRD. However, the contribution of manufacturing firms to green innovation, competitiveness and sustainable value creation remains underexplored and therefore requires additional empirical investigation in the context of CSRD. Although the CSRD does not bind most Chinese manufacturers directly, its reach extends to them through EU customers, investors and supply chains that increasingly require CSRD-consistent data. CSRD alignment here therefore denotes the extent to which a firm voluntarily brings its sustainability reporting into line with CSRD and ESRS requirements.

Green innovation encompasses environmentally friendly technologies, clean production, and product design, which are among the major elements of sustainable transition in China (Hu & Nan, 2026). Braun (2026) noted that the CSRD has considerable advantages for companies, such as increased competitiveness, increased investment preparedness, and enhanced congruence with new regulatory requirements. Moreover, Wang et al. (2025) demonstrate that green innovation positively affects firm-level productivity among manufacturing firms in China and the United States, with design patents having particularly strong effects on green total factor productivity in China.

The extent to which CSRD alignment translates into green innovation and competitiveness is likely to depend on two conditions. The first is environmental uncertainty. Chen et al. (2022) find that, among Chinese listed firms, uncertainty reduces both innovation input and innovation output. The second is external pressure. Singh et al. (2022) report that stakeholder pressure strengthens green dynamic capabilities in manufacturing SMEs and that these capabilities, rather than the pressure itself, account for higher green innovation and performance.

Evidence on the competitive consequences of CSRD alignment for Chinese manufacturers remains limited, and the mediating role of green innovation in this relationship has received even less attention. Mandatory sustainability disclosure appears to stimulate green innovation, although the effect is uneven. Hong et al. (2020) observe stronger responses in large firms, state-owned firms and pollution-intensive industries, and Ren et al. (2023) observe stronger responses where environmental enforcement is stringent. Jiang et al. (2026) further show that executives' environmental awareness strengthens the effect of normative and stakeholder pressures on green innovation. Environmental uncertainty and institutional pressure have not, however, been examined jointly as conditions on the relationship between CSRD alignment and green innovation. The present study addresses this gap in the context of China's manufacturing sector, examining whether CSRD alignment translates into competitiveness through green innovation and how environmental uncertainty and institutional pressure condition that process.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Institutional theory starts from the observation that what firms do is shaped less by internal calculation than by the regulatory rules, societal expectations, cultural norms and professional

standards that surround them (DiMaggio & Powell, 1983). In the same way, Gomez-Trujillo et al. (2024) show that firms that embed sustainability in their strategy achieve legitimacy and sustain a competitive advantage over time. In the context of Chinese manufacturing, stringent governmental rules and environmental policy expectations generate coercive, normative, and mimetic forces that compel enterprises to align with the CSRD. A recent study by Abideen and Fuling (2024) reported that Chinese firms that embrace transparent and responsible practices not only improve their standing in the market but also exert a notable influence on driving sustainable investment. Institutional theory therefore offers a fitting lens for understanding why firms align their reporting with the CSRD in response to external expectations.

Research on manufacturing firms in developing economies has demonstrated that green sustainability practices, combined with eco-regulatory compliance, positively drive the sustainable performance of firms in economic, social, and environmental terms (Opoku, 2025). Institutional pressure also bears on competitiveness: firms comply with mandates and align with national sustainability goals partly to avoid environmental and reputational risk. Environmental uncertainty, understood here as unpredictability in regulation, markets and technology, is treated as a moderator. Zhu et al. (2024) show that environmental dynamism and complexity condition the effect of institutional pressures on eco-innovation, which suggests that uncertainty may likewise condition how firms respond to CSRD-driven pressure for green innovation. It is therefore modelled as a boundary condition.

2.1 Hypothesis Development

2.1.1 CSRD Alignment and Firm Competitiveness

By aligning with the CSRD, Chinese manufacturing companies, which are increasingly subject to regulatory challenges, investor demands, and pressures in the global market, can increase their legitimacy and reduce information asymmetries, strengthening their institutional position. Li et al. (2026), studying EU-listed firms, reported that CSRD enhances firm performance through maximizing management efficiency and operating efficiency and realizing significant outcomes in terms of environmental, social and governance performance. Consequently, CSRD alignment not only implies compliance with regulations but also serves as an initiative that enables organizations to achieve improved financial and nonfinancial performance, which, in turn, puts organizations in a better position to compete in local and global markets. Thus, we hypothesize the following:

H1: CSRD alignment has a positive and significant effect on firm competitiveness.

2.1.2 CSRD Alignment and Green Innovation

CSRD is crucial for promoting green innovation, especially within highly regulated and ecologically hazardous sectors such as the manufacturing sector. Drawing on legitimacy and stakeholder theories, Velte (2026) argued that the CSRD increased pressure on firms to enhance sustainability reporting transparency, while cautioning that the EU Omnibus amendments may weaken this pressure. In China, firms subject to mandatory CSR disclosure demonstrate significantly higher green innovation performance, with this effect being particularly pronounced

among state-owned enterprises (Ren et al., 2023; Hong et al., 2020) and pollution-intensive industries (Hong et al., 2020). From an institutional theory perspective, firms tend to gain legitimacy by aligning with the CSRD, as coercive and normative forces compel them to realign their practices with social norms or expectations through green innovation. Accordingly, we hypothesize the following:

H2: CSRD alignment has a positive and significant effect on green innovation.

2.1.3 Green Innovation and Firm Competitiveness

Green innovation has been shown to be the channel through which a green organizational culture translates into better organizational performance (Imran & Jingzu, 2022). Cost reduction and government support are among the strongest drivers of green innovation adoption in manufacturing firms (Ullah et al., 2022). Furthermore, Owusu et al. (2024) showed that green innovation practices mediate the link between corporate social responsibility and environmental performance in manufacturing firms, whereas competitive advantage strengthens the link between CSR and environmental performance. Accordingly, manufacturing firms that invest in green innovation are more likely to realize sustainable improvements in performance, higher strategic resilience and greater competitiveness both regionally and globally. Drawing on the preceding discussion, the following hypothesis is proposed:

H3: Green innovation has a positive and significant effect on firm competitiveness.

2.1.4 Green Innovation as a Mediator between CSRD Alignment and Firm Competitiveness

Research has demonstrated that ESG disclosure significantly fosters corporate green innovation by relieving financing constraints and drawing analyst attention (Ruan et al., 2024), while ESG performance is positively correlated with sustainable green innovation, particularly when coupled with corporate digital transformation (Li & Rasiah, 2024). Moreover, green innovation strategies can strengthen green innovative competitive advantage and thereby support sustainable innovative performance (Hayat & Qingyu, 2024). Thus, CSRD alignment indirectly enhances a firm's competitiveness by strengthening the critical dimension of green innovation, which is an integral (mediating) aspect of sustainability-oriented business. Accordingly, we propose the following hypothesis:

H4: Green innovation positively mediates the relationship between CSRD alignment and firm competitiveness.

2.1.5 Moderating Effect of Environmental Uncertainty on the Relationship between CSRD Alignment and Green Innovation

According to Hermundsdottir and Aspelund (2022), who studied Norwegian manufacturing firms, adopting sustainability strategies encourages manufacturing firms to pursue environmental innovations, ultimately strengthening firm performance through greater value creation, lower costs, and reduced risk exposure. Environmental uncertainty inhibits green innovation by undermining transparency and curtailing R&D investment (Feng & Ma, 2024), though government subsidies can attenuate this effect. Nevertheless, it can also be argued that the positive relationship

between CSRD and green innovation may be enhanced by environmental uncertainty, because uncertainty may lead firms to consider sustainability reporting as a strategic instrument for managing the complex world and increasing their future resilience. Accordingly, we propose the following hypothesis:

H5: Environmental uncertainty positively moderates the relationship between CSRD alignment and green innovation.

2.1.6 Moderating Effect of Institutional Pressure on the Relationship between CSRD Alignment and Green Innovation

Institutional pressures, including coercive regulatory pressure, normative expectations, and mimetic pressure from successful industry peers, can strongly influence firms' green innovation outcomes. Zhu et al. (2024) found that normative, mimetic, and coercive pressures all promote eco-innovation and that environmental complexity and dynamism moderate some of these relationships. Widyantoro et al. (2025) demonstrate that stakeholder pressures drive green innovation through green dynamic capabilities, a pathway that sequentially extends to financial performance. Ma et al. (2026) reported that institutional pressures, particularly those arising from environmental regulations and green market demands, strengthen firms' green knowledge base, which subsequently fosters innovations in both green processes and green products, ultimately contributing to sustainable performance in manufacturing firms. Sharma (2026) shows that firms respond differently to CSRD-related pressures: large listed firms tend to adopt acquiescence strategies, whereas SMEs and non-listed firms more often use compromise or avoidance strategies because of resource constraints and implementation challenges. Institutional pressure is therefore expected to strengthen the link between CSRD alignment and green innovation by heightening external accountability and reputational risk. The proposed relationships are depicted in Fig. 1.

H6: Institutional pressure positively moderates the relationship between CSRD alignment and green innovation.

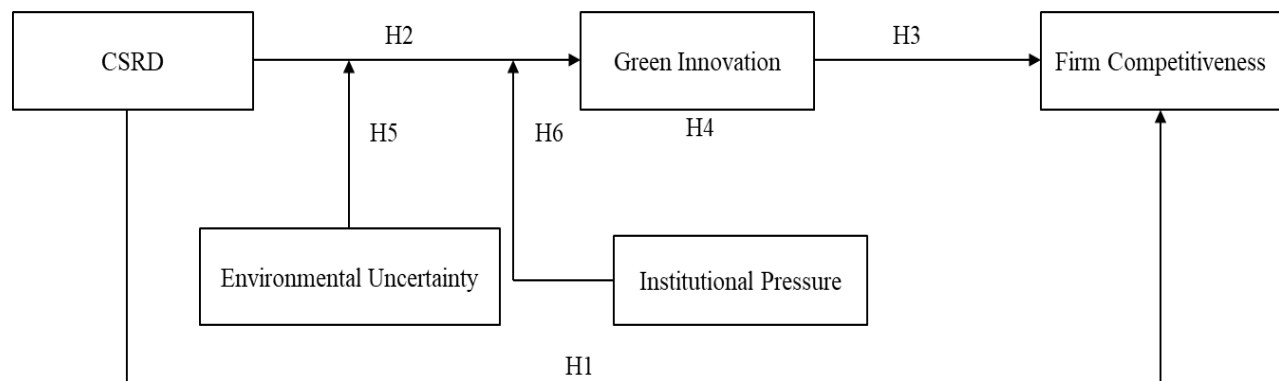


Fig. 1 – Research Model. Source: own research

3. METHODOLOGY

3.1 Measures

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The measurement items were adapted from established studies and customized to the Chinese manufacturing sector. A pilot study with managers of Chinese manufacturing companies was conducted to test item clarity and relevance, and wordings were changed on the basis of the feedback. CSRD alignment is measured using six items developed by the authors on the basis of the key disclosure requirements outlined in the CSRD and ESRS (European Parliament and Council, 2022; European Commission, 2023) to assess the extent and quality of sustainability reporting practices within organizations. Green innovation is measured using six items adapted from Chen et al. (2006), covering green product innovation and green process innovation. Firm competitiveness is measured using six items adapted from Arraya and Ferreira (2025). We operationalize environmental uncertainty with five items adapted from Chen and Tian (2022), who operationalized environmental uncertainty following Jaworski and Kohli (1993), and institutional pressure with four items covering coercive, normative, and mimetic dimensions (Zhu et al., 2024), all on a five-point Likert scale (Tab. 1).

Tab. 1 – Measurements of Constructs. Source: own research

S. N	Construct	No. of Items	Sources
1	CSRD	6	(European Parliament and Council, 2022; European Commission, 2023)
2	Green Innovation	6	Chen et al. (2006)
3	Firm Competitiveness	6	Arraya and Ferreira (2025)
4	Environmental Uncertainty	5	Chen and Tian (2022); Jaworski and Kohli (1993)
5	Institutional Pressure	4	Zhu et al. (2024)

3.2 Population, Data Collection Method and Sample Size

The study draws on Chinese manufacturing firms, a setting frequently examined in green innovation research (e.g., Qiu et al., 2020). Managers were chosen as respondents because they are the people who actually make sustainability-related decisions in these firms (Ofori-Owusu et al., 2024). Data were gathered with a structured questionnaire, and respondents were selected purposively to ensure that they were knowledgeable about their firm's reporting and innovation practices. The sample consists of firms in the Chinese manufacturing sector, spanning manufacturing and the manufacturing-related sub-sectors of chemicals and pharmaceuticals, construction and materials, and electronics and electrical. These industries were chosen because of their exposure to sustainability requirements and green innovation processes.

The target population comprises roughly 5,000 managers employed in small, medium-sized and large manufacturing companies in Guangdong, Jiangsu and Zhejiang, China's three leading manufacturing provinces. We obtained 320 usable responses from 550 questionnaires distributed (a 58.18% response rate). Because the study tests a structural model rather than estimating population parameters, sample adequacy was judged against PLS-SEM criteria: the largest number of predictors directed at any construct is five (green innovation), so the 10-times rule implies a minimum of 50 cases (Hair et al., 2014), which the sample comfortably exceeds.

4. RESULTS

4.1 Data Analysis

The hypotheses were tested with partial least squares structural equation modeling (PLS-SEM) in SmartPLS 4 (Ringle et al., 2024). PLS-SEM was chosen because the model is prediction-oriented and combines a mediator with two interaction terms, a configuration the method handles well (Legate et al., 2023), and because it copes with non-normal data and moderate sample sizes (Hair et al., 2022).

4.2 Common Method Bias (CMB)

Because all variables were reported by the same respondents at one point in time, we checked for common method bias in two ways. First, an unrotated principal component analysis of all items (Harman's single-factor test; Podsakoff et al., 2003) extracted several components with eigenvalues above 1, and the first of these fell well short of accounting for most of the variance. Since this test is now widely regarded as a weak safeguard (Howard et al., 2024; Podsakoff et al., 2024), we also ran Kock's (2015) full collinearity procedure, in which every construct is regressed on all the others; the resulting construct-level VIFs were all below the 3.3 cut-off (maximum 2.262). Taken together, the two checks give no indication that method bias distorts the results.

Tab. 2 – Demographic information of the respondents (N = 320). Source: own research

Demographic	Description	Frequency	Percentage (%)
Gender	Male	201	62.8%
	Female	119	37.2%
Age	25–34 years	77	24.1%
	35–44 years	136	42.5%
	45–54 years	82	25.6%
	55 years and above	25	7.8%
Education Level	Bachelor's degree	101	31.6%
	Master's degree	163	50.9%
	Doctorate (PhD)	56	17.5%
Respondent Position	Senior Managers	126	39.4%
	Sustainability Officers	108	33.8%
	R&D Managers	86	26.9%
Years of Experience	Less than 5 years	46	14.4%
	5–10 years	96	30.0%
	11–15 years	91	28.4%
	More than 15 years	87	27.2%
Industry Sector	Manufacturing	131	40.9%
	Electronics & Electrical	76	23.8%
	Chemicals & Pharmaceuticals	61	19.1%
	Construction & Materials	52	16.3%
Company Size	Less than 250 employees	81	25.3%
	250–1,000 employees	115	35.9%
	More than 1,000 employees	124	38.8%
Geographical Location	Guangdong	126	39.4%
	Jiangsu	103	32.2%

	Zhejiang	91	28.4%
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Tab. 2 summarizes the respondents' profile. Most respondents were men (62.8%), aged 35–44 years (42.5%) and held a master's degree (50.9%). Senior managers (39.4%), sustainability officers (33.8%) and R&D managers (26.9%) were represented, confirming that responses came from individuals involved in sustainability decision-making, and 85.6% had at least five years of experience. Manufacturing was the largest sector (40.9%), firms with more than 1,000 employees formed the largest size group (38.8%), and respondents were distributed across Guangdong (39.4%), Jiangsu (32.2%) and Zhejiang (28.4%).

4.3 Measurement Model

The measurement model was judged on four properties. For indicator reliability we looked at the outer loadings; Hair et al. (2019) regard 0.708 as the point at which an item explains at least half of its own variance, although items that load somewhat lower can be kept when the construct-level reliability and validity statistics are sound (Hair et al., 2022). Internal consistency was gauged with Cronbach's alpha and with composite reliability (ρ_c), both of which are expected to clear 0.70 (Hair et al., 2022; Sarstedt et al., 2022). Convergent validity rests on the average variance extracted (AVE), which needs to be above 0.50 for a construct to capture more of its indicators' variance than error does (Hair et al., 2022). Discriminant validity was checked in two ways, through the Fornell–Larcker comparison (Fornell & Larcker, 1981) and through the heterotrait–monotrait ratio (HTMT), for which 0.85 serves as the conservative ceiling (Henseler et al., 2015). Finally, collinearity was inspected using variance inflation factors. Indicator VIFs ranged from 1.197 to 4.394 and inner-model VIFs from 1.293 to 2.262 for the constructs; the two interaction terms showed higher values (3.005 and 3.979), as expected for product terms that are collinear with their own components. All values remained below the level of 5 at which Hair et al. (2019) consider collinearity problematic. Fig. 2 shows the estimated model.

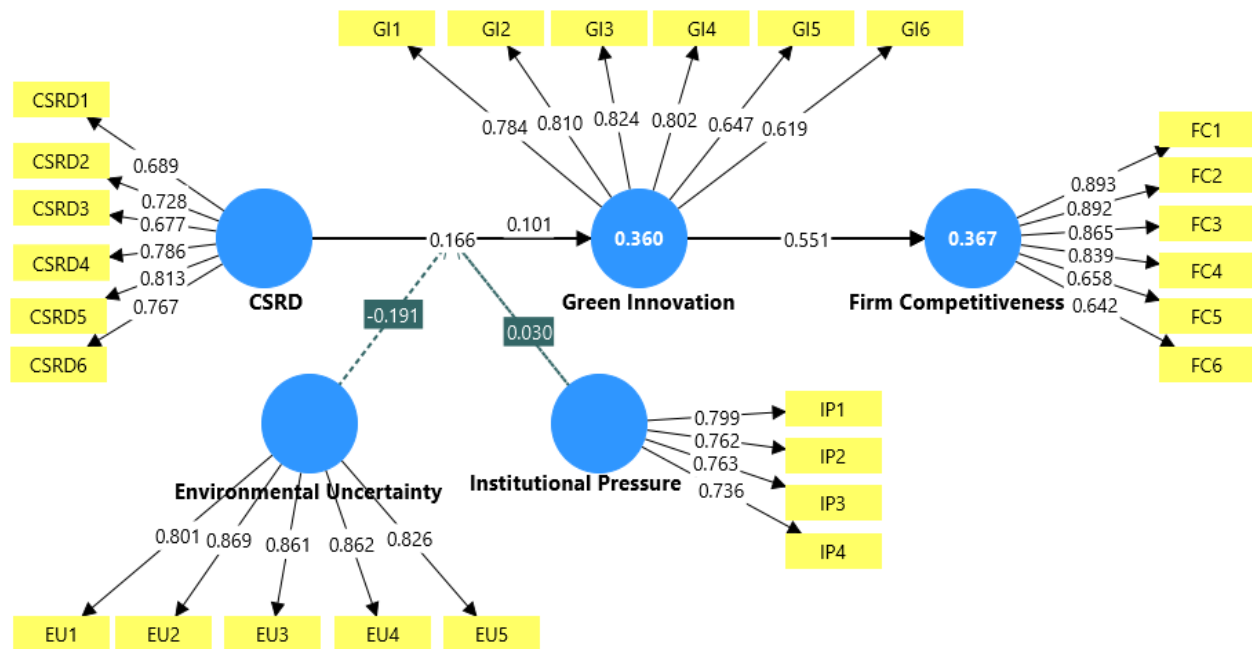


Fig. 2 – PLS-SEM results (outer loadings, path coefficients and R² values). Source: own research

The results in Tab. 3 satisfy these requirements. Six items (CSR1, CSR3, GI5, GI6, FC5 and FC6) load between 0.60 and 0.70; we kept them because dropping them barely moved ρ or AVE and because each captures an aspect of its construct that the remaining items do not (Hair et al., 2022). Across the five constructs, Cronbach's alpha runs from 0.770 to 0.901 and ρ from 0.850 to 0.925, and AVE lies between 0.555 and 0.713, so every construct clears both the reliability and the convergent validity benchmarks.

Tab. 3 – Assessment of Construct Reliability and Validity. Source: own research

Constructs	Items codes	Outer Loadings	Cronbach's alpha (α)	CR (ρ)	AVE
CSR	CSR1	0.689	0.846	0.882	0.555
	CSR2	0.728			
	CSR3	0.677			
	CSR4	0.786			
	CSR5	0.813			
	CSR6	0.767			
Green Innovation	GI1	0.784	0.844	0.885	0.566
	GI2	0.810			
	GI3	0.824			
	GI4	0.802			
	GI5	0.647			
	GI6	0.619			
Firm Competitiveness	FC1	0.893	0.887	0.916	0.648
	FC2	0.892			
	FC3	0.865			

	FC4	0.839			
	FC5	0.658			
	FC6	0.642			
Environmental Uncertainty	EU1	0.801	0.901	0.925	0.713
	EU2	0.869			
	EU3	0.861			
	EU4	0.862			
	EU5	0.826			
Institutional Pressure	IP1	0.799	0.770	0.850	0.586
	IP2	0.762			
	IP3	0.763			
	IP4	0.736			

Tab. 4 applies the Fornell–Larcker test: a construct is judged distinct when it shares more variance with its own indicators (the square root of its AVE, shown on the diagonal) than with any other construct (Fornell & Larcker, 1981). In every row and column of the table the diagonal entry (0.745 to 0.844) is the largest value, so the five constructs are empirically separable.

Tab. 4 – Discriminant validity Fornell–Larcker criterion. Source: own research

Constructs	CSRD	EU	FC	GI	IP
CSRD	0.745				
EU	0.375	0.844			
FC	0.364	0.215	0.805		
GI	0.476	0.333	0.599	0.752	
IP	0.585	0.609	0.457	0.532	0.765

The HTMT ratios in Tab. 5 offer a more demanding check (Henseler et al., 2015). None of the ten ratios reaches the 0.85 ceiling; the two largest, institutional pressure with environmental uncertainty (0.733) and institutional pressure with CSRD alignment (0.705), still leave a clear margin, which confirms the Fornell–Larcker result.

Tab. 5 – Discriminant validity (HTMT). Source: own research

Constructs	CSRD	EU	FC	GI	IP
CSRD					
EU	0.404				
FC	0.397	0.233			
GI	0.505	0.338	0.679		
IP	0.705	0.733	0.533	0.580	

Note: CSRD (CSRD alignment), GI (green innovation), FC (firm competitiveness), EU (environmental uncertainty), IP (institutional pressure).

4.4 Structural Model

Path coefficients (β) and their standard errors, t values and p values were obtained by bootstrapping the model 5,000 times with percentile confidence intervals and a two-tailed test; the standardized coefficients convey both the size and the sign of each relationship (Hair et al., 2022). A path was counted as significant at the 5% level, that is, when its t value exceeded 1.96 (Kock, 2016). As Tab. 6 shows, CSRD alignment has a positive and significant direct effect on FC (H1: $\beta = 0.101$, $t = 2.234$, $p = 0.026$) and a significant positive effect on GI (H2: $\beta = 0.166$, $t = 2.579$, $p = 0.010$). GI in turn has a strong positive effect on FC (H3: $\beta = 0.551$, $t = 12.380$, $p < 0.001$), making it the dominant driver of competitiveness in the model. The indirect path from CSRD alignment to FC via GI is likewise significant (H4: $\beta = 0.092$, $t = 2.589$, $p = 0.010$; 95% CI [0.024, 0.164]), so H4 is supported. As the direct (H1) and indirect (H4) effects are both significant and positive, green innovation plays a complementary partial mediating role (Hair et al., 2022); the total effect of CSRD alignment on FC is $\beta = 0.193$ ($t = 3.545$, $p < 0.001$). Regarding the main effects of the moderators, institutional pressure significantly and positively affects GI ($\beta = 0.328$, $t = 4.970$, $p < 0.001$), whereas environmental uncertainty does not ($\beta = 0.019$, $t = 0.337$, $p = 0.736$).

Moreover, the results indicate that EU significantly weakens the link between CSRD alignment and GI (H5: $\beta = -0.191$, $t = 3.598$, $p < 0.001$). Because a positive moderating effect was hypothesized, H5 is not supported. The simple slope analysis shows that the effect of CSRD alignment on GI is strong when EU is low (-1 SD: $\beta = 0.358$, $p < 0.001$) but disappears when EU is high ($+1$ SD: $\beta = -0.025$, $p = 0.750$). Contrary to expectation, uncertainty did not prompt firms to intensify sustainability-oriented innovation; the negative interaction suggests that it instead raises managerial caution and reduces commitment of resources to long-term green initiatives. Institutional pressure does not moderate the link between CSRD alignment and GI (H6: $\beta = 0.030$, $t = 0.567$, $p = 0.571$). Overall, H1–H4 are supported and H5 and H6 are not.

Tab. 6 – Hypotheses results. Source: own research

Hypothesis	Paths	β -value	SE	t values	p values
H1	CSRD $\rightarrow$ FC (direct)	0.101	0.045	2.234	0.026
H2	CSRD $\rightarrow$ GI	0.166	0.065	2.579	0.010
H3	GI $\rightarrow$ FC	0.551	0.044	12.380	< 0.001
H4	CSRD $\rightarrow$ GI $\rightarrow$ FC (indirect)	0.092	0.035	2.589	0.010
H5	EU $\times$ CSRD $\rightarrow$ GI	-0.191	0.053	3.598	< 0.001
H6	IP $\times$ CSRD $\rightarrow$ GI	0.030	0.053	0.567	0.571
—	IP $\rightarrow$ GI (main effect)	0.328	0.066	4.970	< 0.001
—	EU $\rightarrow$ GI (main effect)	0.019	0.058	0.337	0.736

Note: CSRD (CSRD alignment), GI (green innovation), FC (firm competitiveness), EU (environmental uncertainty), IP (institutional pressure).

Tab. 7 sets out the f^2 effect sizes and the R^2 values. Read against Cohen's (1988) benchmarks, under which 0.02, 0.15 and 0.35 mark the lower bounds of small, medium and large effects, the picture is uneven: green innovation exerts a large effect on firm competitiveness ($f^2 = 0.371$), whereas CSRD alignment's effects on green innovation ($f^2 = 0.019$) and directly on

competitiveness ($f^2 = 0.013$) both fall below the small-effect threshold. The interaction between environmental uncertainty and CSRD alignment has a small effect size ($f^2 = 0.034$), which is typical of moderating effects, whereas the main effect of environmental uncertainty is negligible ($f^2 = 0.000$). Institutional pressure has a small main effect on green innovation ($f^2 = 0.077$), but its interaction with CSRD alignment is negligible ($f^2 = 0.001$), consistent with its non-significant moderating influence.

Thus, although CSRD alignment significantly affects both green innovation and firm competitiveness, its effect sizes are negligible, indicating that it is one of several drivers of green innovation and that roughly half of its influence on competitiveness operates through green innovation. The R^2 values of 0.360 (green innovation) and 0.367 (firm competitiveness) indicate weak-to-moderate explanatory power (Hair et al., 2019).

Tab. 7 – Effect size (f^2) and coefficient of determination (R^2). Source: own research

Constructs	Firm Competitiveness	Green Innovation	R^2
CSRD	0.013	0.019	
Environmental Uncertainty		0.000	
EU × CSRD		0.034	
Green Innovation	0.371		0.360
Institutional Pressure		0.077	
IP × CSRD		0.001	
Firm Competitiveness			0.367

4.5 Model Fit

The global fit statistics in Tab. 8 are modest. SRMR is 0.111 for the saturated model and 0.110 for the estimated model, above the 0.08 level that Hu and Bentler (1999) proposed, which means that the model-implied correlations depart from the observed ones to a noticeable degree; NFI (0.647 and 0.646) likewise sits below the customary 0.90 mark (Bentler & Bonett, 1980). These indices were developed for covariance-based SEM, and their use in PLS-SEM is still being worked out, so Hair et al. (2019) advise against reading too much into them. Given that the measurement model is sound, the hypothesized paths are estimated precisely and collinearity is not a concern, we treat the model as adequate for its explanatory and predictive purpose while acknowledging the weak global fit.

Tab. 8 – Model fit indices. Source: own research

Criteria	Saturated model	Estimated model
SRMR	0.111	0.110
d_uls	4.666	4.574
d_g	1.365	1.392
Chi-square	2290.497	2294.048
NFI	0.647	0.646

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5. DISCUSSION AND CONCLUSION

CSRD alignment is positively associated with both firm competitiveness ($\beta = 0.101$) and green innovation ($\beta = 0.166$). The direct effect on competitiveness is small; the indirect effect through green innovation is of comparable magnitude ($\beta = 0.092$) and accounts for approximately 48% of the total effect ($\beta = 0.193$). Green innovation therefore partially mediates the relationship, and the direct path remains significant although its effect size is negligible ($f^2 = 0.013$). Alignment thus contributes to competitiveness less as disclosure in itself than as a prompt for firms to modify their innovation activity, green innovation being the strongest predictor of competitiveness in the model ($\beta = 0.551$, $f^2 = 0.371$).

This interpretation is consistent with the wider evidence on environmental regulation. Lajmi and Shiri (2025) find that command-and-control regulation lowers the performance of European high-polluting firms in the short term and raises it in the long term, with green innovation carrying the long-term effect; Guo et al. (2023) report a comparable innovation response among heavily polluting listed firms in China. The present setting differs in two respects. The regulation concerned is a reporting requirement rather than an emission standard, and the firms are Chinese manufacturers that align with it voluntarily. The association between green innovation and competitiveness has been documented previously, including by Padilla-Lozano and Collazzo (2022) in Ecuadorian manufacturing; in the present model it is the channel through which disclosure is converted into competitive advantage.

Moreover, the moderation findings provide additional insight, indicating that greater environmental uncertainty diminishes the positive influence of CSRD alignment on green innovation; the effect is strong when uncertainty is low but becomes non-significant when uncertainty is high. These results are in line with the findings of Hu et al. (2023), who argue that environmental policy uncertainty prevents potential green investments because of unpredictable policy content and uncertain enforcement, significantly inhibiting firms' willingness to commit to green investment activities. H6 is not supported: although institutional theory suggests that coercive, normative and mimetic pressures could reinforce the relationship between CSRD alignment and green innovation, the interaction was positive but not significant ($\beta = 0.030$, $p = 0.571$). Institutional pressure has a significant positive association with green innovation ($\beta = 0.328$, $p < 0.001$), albeit with a small effect size ($f^2 = 0.077$), suggesting that it drives green innovation independently rather than by amplifying the effect of sustainability reporting. The non-significant moderation implies that in Chinese manufacturing firms, whenever firms have followed government mandates (e.g., greenhouse gas emission reduction policies) for environmental compliance, there might not be external pressures (e.g., industry competition and stakeholder expectations) powerful enough to further advance sustainability-driven innovation activities.

5.1 Implications of the Study

Theoretically, this study clarifies the processes and boundary conditions that shape the association between CSRD alignment and firm competitiveness: green innovation partially mediates the relationship, and environmental uncertainty moderates the first stage of that pathway, from CSRD alignment to green innovation. Practically, aligning sustainability reporting with the CSRD fosters transparency and green innovation and thereby strengthens firms' competitive position, although

the direct effect is small and about half of the benefit operates through innovation. Policymakers can draw two conclusions. Because uncertainty weakens the link between CSRD alignment and green innovation, the stability and predictability of the reporting regime matter alongside its content. Long-term reporting guidance, green finance incentives and predictable compliance expectations reduce that uncertainty and make it more likely that alignment leads to substantive innovation. Reporting systems should also reward investment in green technology, rather than disclosure alone. For managers of Chinese manufacturing firms, the implication is that CSRD-aligned reporting requires internal support in the form of innovation capability, risk-management routines and resource-allocation mechanisms that can sustain green innovation when markets and regulation are volatile.

Declarations:

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