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Strategic decoupling through legitimacy: the sustainability-innovation gap in the food processing sector and its health implications

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Abstract

Background Environmental and public health impacts are critical in the food processing industry. To demonstrate responsiveness to stakeholder expectations, firms foreground sustainability reporting through frameworks such as Environmental, Social, and Governance (ESG) and Corporate Social Responsibility (CSR). Yet the sustainability rhetoric usually centers on visible, marketable, and peripheral dimensions, including packaging, energy use, and philanthropy. In contrast, domains within their core operations, including product composition, nutritional quality, and marketing ethics, receive limited attention. Subsequently, concerns over the commercial determinants of health rise, particularly for vulnerable populations.

Methods The study follows an embedded mixed-methods design to examine whether sustainability disclosures align with firms' innovation strategies. Using 2023 data from 90 multinational or export-oriented food processing firms, hierarchical and multiple regression models assess the effects of ESG sub-dimensions and CSR scores on R&D expenditure, controlling for market capitalization (MC). To complement the quantitative analysis, the study includes a qualitative examination of selected firms, illustrating how sustainability-innovation gaps manifest in practice.

Results Findings reveal no systematic alignment between sustainability and innovation strategies. The environmental dimension shows a marginally positive yet statistically insignificant relationship with R&D, while social, governance, and CSR metrics exhibit no meaningful association. MC remains the strongest predictor of R&D, highlighting that financial and organizational capacity drives innovation rather than sustainability commitment. Notably, CSR aligns more closely with environmental than social performance, indicating a selective legitimacy orientation. Firm-level evidence also reflects the patterns of symbolic compliance, illustrating how strong ESG scores can coexist with weak sustainability integration.

Conclusion The weak coupling between sustainability communication and innovation behavior exposes a structural gap between corporate legitimacy efforts and tangible outcomes for sustainable development. Firms that prioritize reputational visibility over substantive innovation reinforce health inequities and constrain systemic reform. To enhance environmental and public health outcomes, both corporate and regulatory strategies should move beyond symbolic compliance toward outcome-based accountability. Such a shift can better incentivize innovation that enhances nutritional quality, strengthens social equity, and protects environmental integrity.

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Keywords Strategic decoupling, Sustainability reporting, Environmental, Social, and Governance (ESG), Corporate Social Responsibility (CSR), Strategic management, Food processing industry, Commercial determinants of health, Public health implications

Background

The food processing industry has a crucial role in providing safe and nutritious products for society. However, it draws increasing criticism and pressure to adopt more sustainable operations, particularly due to its potential risks to community health and environmental degradation [1–6]. The industry is highly sensitive, so companies pursue legitimacy more actively as reputation is typically more fragile [7, 8].

ESG and CSR reporting are common instruments in sustainability reporting, communicating firms' alignment with stakeholder priorities [9, 10]. The ESG framework provides specific evaluation criteria to measure environmental (E), social (S), and governance (G) performance [9], and CSR represents a company's self-initiated activities to create positive social and environmental results [10, 11]. These instruments are particularly relevant to large corporations in this sensitive sector, given their amplified visibility [7, 9, 12]. Therefore, sustainability themes such as community support, employee well-being, and eco-friendly technologies are commonly featured in company reports [13].

Research and Development (R&D) is an indicator of firms' innovation level, and is one of the building blocks for achieving the Sustainable Development Goals (SDGs) [14–17]. Previous studies suggest that strong sustainability performance can foster innovation toward environmental protection and public health [18–20]. Yet, R&D investments usually concentrate on profit-oriented goals, such as cost efficiency, shelf-life extension, sensory engineering, or marketing strategies, whereas nutritional value and social equity receive little attention [6, 21–24]. Thus, especially large corporations reliant on reputation tend to sustain legitimacy primarily via disclosures and policy commitments [25–27]. Subsequently, corporate communication diverges from actual operations, resulting in strategic decoupling [28].

This study investigates how sustainability reporting through ESG sub-scores (E, S, G) and CSR relates to innovation investment, measured by R&D expenditure, among internationally active food processing firms. It further examines the internal consistency of sustainability dimensions, focusing on whether CSR scores correspond with environmental and social performance or instead reflect selective disclosure across these domains. In addition to the quantitative analysis, illustrative firm-level cases are used to contextualize the results and explore how R&D and sustainability commitments manifest in organizational practice. Subsequently, the research addresses two main questions:

RQ_1 To what extent are ESG and CSR scores aligned with R&D investment strategies among internationally active food processing firms?

RQ_2 To what extent are Environmental and Social performance scores associated with CSR performance in internationally active food processing firms?

The analysis centers on multinational corporations (MNCs) and export-oriented firms, which operate under stronger global sustainability pressures and influence transnational health and environmental outcomes. By addressing these questions, the study seeks to clarify whether sustainability communication is strategically integrated or symbolically detached from core innovation strategies, providing both theoretical and policy-relevant insights for this globally sensitive sector.

ESG, CSR, and innovation in the food processing sector

The ESG framework reflects a weighted average of three sub-scores [29]. The environmental pillar (E) evaluates a company's waste and pollution management, carbon emissions, and resource efficiency. It is typically emphasized in high-impact sectors such as food processing [9, 30, 31]. The social score (S) reflects a company's responsibility toward employees, consumers, and communities, factors known to enhance brand reputation and stakeholder trust [32, 33]. Governance (G), on the other hand, encompasses internal mechanisms such as board structure, ethical leadership, and transparency [32, 34]. Previous research indicates that ESG metrics are increasingly influencing strategic decision-making. The metrics expand the notion of firm performance beyond financial returns by including environmental and social value creation [9, 35]. Thus, it is especially important in the food industry, where sustainability is increasingly viewed as a strategic instrument to maintain corporate resilience and public well-being simultaneously [36–38].

First introduced by Bowen as a company's commitment to policies beneficial to society [39], CSR has gained widespread traction across sectors in recent years [40]. The concept covers voluntary or charitable activities aimed at improving public image and ensuring legal compliance [41, 42]. While some companies perceive CSR as a burden due to limited awareness or resources [42], others frame it as a strategic approach to maintain public trust, ethical decision-making, and long-term resilience

[43]. Issues of food safety, accessibility, and ethical marketing usually intersect with CSR practices in the food processing industry [40, 43].

R&D involves systematic activities that apply scientific and technological knowledge to improve products, processes, and services [14–16]. Sustainability in R&D is vital in the food processing industry for its direct impact on environmental and public health outcomes [36, 44]. Such efforts particularly link to food security and rising consumer demand for healthier options [45, 46]. Prior research indicates that firms with strong ESG or CSR profiles tend to invest in innovations that support sustainable production and climate action, encouraged by stakeholder expectations and reputational concerns [18–20, 46–49]. The use of emerging technologies such as artificial intelligence (AI), high hydrostatic pressure (HPP), and plasma-activated water (PAW) is a promising direction to enhance efficiency and food safety [46, 47]. Other recognized examples include cleaner production techniques, transparent labeling, nutrient-conscious product design, and ICT-based redistribution platforms [48, 50, 51].

Yet, the direction and strength of these relationships vary across contexts. High entry costs, evolving technologies, regulatory uncertainty, and fragmented supply chains are among the substantial barriers [49, 52]. Large corporations therefore account for most R&D spending, as they possess greater financial resources, broader operational reach, and stronger absorptive capacity [53–56]. Nevertheless, not all forms of innovation contribute toward sustainability objectives. A prominent example of non-sustainable innovation in the food processing sector is the continued development of ultra-processed foods (UPFs). These products are energy-dense and engineered with industrial ingredients and additives to enhance taste, shelf life, and consumer appeal [1, 2, 23–25, 57]. In response to growing public health concerns, food processing companies often adopt reformulation strategies aimed at reducing sugar or fat content in UPFs. As noted by [24], these reformulations frequently substitute one unhealthy ingredient for another, such as replacing sugar with highly refined starches or artificial sweeteners. Therefore, regulatory and stakeholder scrutiny, particularly from institutional investors and public health actors, plays a decisive role in determining whether sustainability practices lead to meaningful innovation or remain largely symbolic [24, 58–62].

Theoretical foundations

This study draws on three complementary foundations to interrogate sustainability practices in food processing firms. Stakeholder theory explains the external pressures and expectations that encourage firms to engage with sustainability initiatives [63–65]. Legitimacy theory accounts for how firms strategically respond to these pressures by framing actions in ways that secure societal approval [66–68]. Strategic decoupling extends this perspective by illustrating how symbolic disclosures may diverge from substantive practices when sustainability commitments are not integrated into innovation [28, 69, 70]. Taken together, a sequential lens clarifies why firms adopt sustainability rhetoric, how they seek legitimacy, and what outcomes emerge when such rhetoric is disconnected from the core activities.

Stakeholder theory and the drive for sustainability

Stakeholder theory establishes a theoretical basis for why firms should engage in sustainability initiatives. Originally proposed by Freeman (1984), the theory challenges shareholder-centric models by emphasizing that long-term organizational success depends on meeting the expectations of a broader range of stakeholders, including employees, consumers, communities, and regulators [63–65].

Within this framework, normative pressures and the pursuit of legitimacy shape firms' sustainability engagement [71, 72]. The food processing industry presents a particularly relevant context for stakeholder theory. Growing awareness of environmental harm, social inequality, and health risks has led consumers, policymakers, and other actors to intensify their scrutiny and call for greater accountability, including transparent practices and adherence to ethical and sustainability standards [73–76].

In response, many companies turn to ESG and CSR frameworks to demonstrate responsibility. When these efforts involve innovations such as healthier ingredients, sustainable packaging, or traceable supply chains, innovation serves to achieve sustainability goals while reinforcing legitimacy [46–49]. However, not all engagement reflects deep commitment. Many firms may engage only superficially prioritizing legitimacy over substantive change, so the extent to which stakeholder influence drives transformative innovation remains unclear [62, 75].

Legitimacy theory and symbolic sustainability

Legitimacy theory delves into how firms respond to external pressures by aligning with societal norms to maintain approval and mitigate reputational risks [66, 77]. Such concerns are particularly evident in the food processing sector, where firms face intense scrutiny over health, environmental, and ethical issues. Long-term survival depends on meeting societal expectations through appropriate systems, and when a legitimacy gap emerges, firms should implement strategies to restore public trust [67, 68, 78, 79].

Notably, these strategies may focus on the perception of conformity with socially accepted standards instead of actual performance [80, 81]. In this parallel, firms may adopt ESG and CSR frameworks primarily to signal alignment with public expectations without aiming genuine sustainability [75, 82]. The literature terms such behavior symbolic sustainability, as it prioritizes reporting, certifications, or public messaging to appear responsible while core business operations continue as usual [83, 84].

Symbolic sustainability initiatives do not always indicate bad faith. The challenge of balancing profitability, stakeholder expectations, and regulatory pressures may lead firms to use sustainability disclosures strategically to maintain legitimacy, by mitigating the high costs of organizational change as much as possible [28, 85, 86]. However, when legitimacy is pursued primarily through symbolic means, sustainability reports may end up becoming tools mostly for image management [87]. For more exaggerated forms, the term greenwashing refers to the deceptive use of selective disclosures or overstated claims to maintain a favorable public image [75, 83, 84, 88]. Such cases lead to strategic decoupling, so ESG and CSR reports diverges from the structural changes, resulting in nutrition insecurity, rising diseases and environmental degradation [1, 2, 24, 46–49, 57, 58].

Strategic decoupling and the innovation disconnect

Strategic decoupling refers to situations that firms adopt sustainability narratives without corresponding behavioral changes. Meyer and Rowan (1977) first introduced the concept within the institutional theory tradition. It addresses the separation between an organization's formal structures, such as policies, disclosures, or certifications, and its day-to-day operations [28, 89], particularly when external expectations conflict with internal efficiency or strategy [69]. In sustainability reporting, the gap between the projected responsible image and actual ESG or CSR performance raising concerns over credibility [89–92].

Existing literature presents conflicting views, indicating the context-dependence of the sustainability-innovation relationship [93–96]. For the food processing industry, sustainability reports are often of limited relevance to real outcomes, as companies usually focus on cost efficiency, branding, or other marketable conveniences [24]. The term "means-ends decoupling" describes such situations of disconnection [70].

Gaps in the literature and contribution of the study

Despite growing academic and institutional interest in ESG and CSR, their connection to innovation remains underexplored, especially in the food processing industry. While some studies link sustainability efforts to responsible innovation [18, 19, 46, 47], others suggest that initiatives often stay symbolic. In many cases, profitable initiatives have been prioritized over substantive sustainability goals, and reputation management remains a central concern in this sector [3, 24, 25, 62, 75]. Such cases lead to the risk of strategic decoupling, wherein sustainability disclosures function more as legitimacy mechanisms than as indicators of strategic action [1, 2, 28, 57, 70]. Moreover, most studies rely on overall ESG scores, without considering their individual dimensions (E, S and G) or examining the alignment between CSR communication and actual practices, leaving open questions about how these indicators relate to tangible innovation investments [33–35, 37, 84, 95, 97].

This research offers multiple contributions: First, it jointly examines sustainability communication (via ESG sub-scores and CSR) and strategic commitment (via R&D investment), unlike previous studies that considered these variables in different models or industry contexts [9–13, 17, 33–40, 44, 59–61, 70, 92–98]. Second, it addresses two complementary forms of strategic decoupling: one between sustainability disclosures and innovation strategies, and another within the disclosure domain itself, namely the potential misalignment between E, S, and CSR performances. Third, the analysis is complemented by illustrative firm-level cases that contextualize statistical findings and expose how strategic decoupling unfolds in practice. Finally, it explains why firms may symbolically comply with sustainability expectations without aligning internal innovation efforts with the theoretical background, highlighting the consequences on public health and environment. The study aims to contribute to academic debate and to offer practical value for corporate managers, policymakers, and international organizations seeking to distinguish symbolic compliance from substantive sustainability efforts.

Figure 1 illustrates a concise overview of the study, including its framework and main insights:

Methodology

Research design and sampling strategy

The study follows an embedded mixed-methods design, in which quantitative results are contextualized through a complementary qualitative component [99]. Specifically, it employs a quantitative, cross-sectional design to assess whether sustainability disclosures are strategically aligned with R&D investment in the food processing industry, and to examine selected firms from the final sample to illustrate how sustainability commitments and innovation investments manifest in practice.

The quantitative analysis focused on firm-level indicators available through the Refinitiv Eikon platform, a widely used source for standardized ESG and financial metrics [100, 101]. It relies exclusively on 2023 data to avoid temporal biases, as pandemic-related disruptions

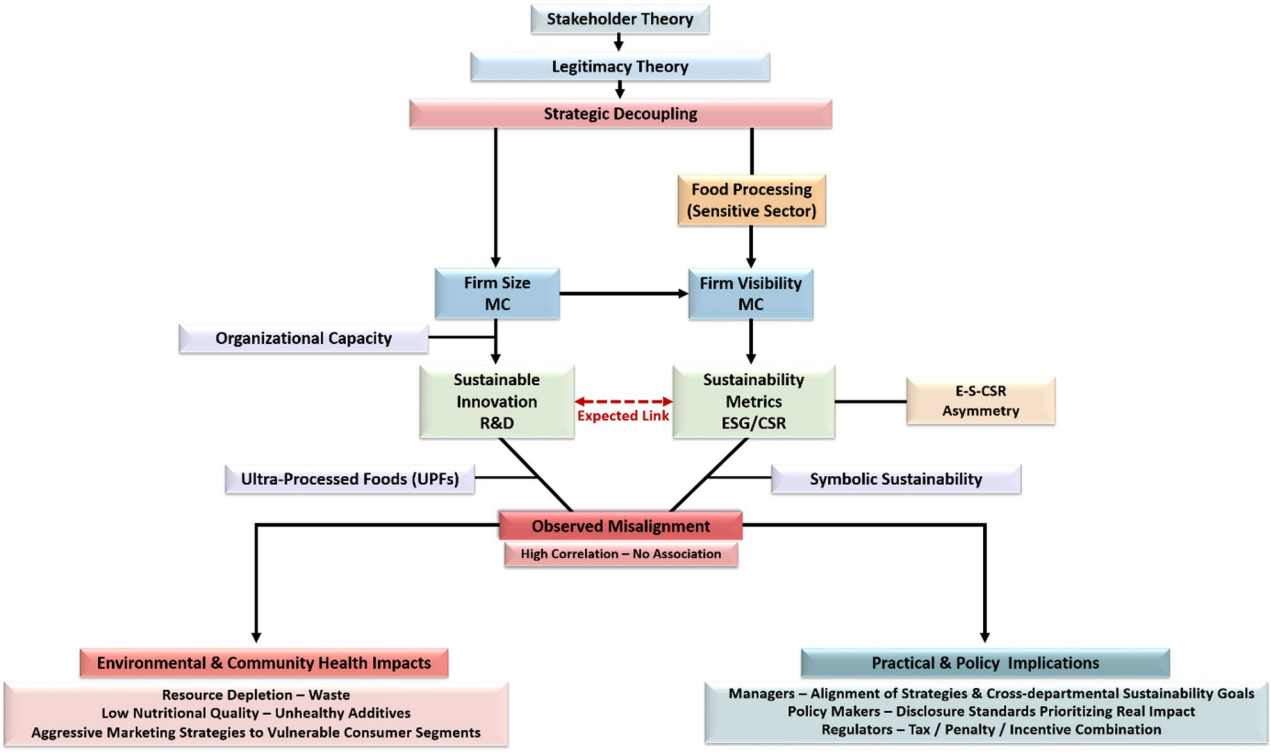

Fig. 1 Overview of study framework and key relationships

to supply chains and ESG reporting persisted through 2022 [33, 45, 102].

The initial sample included 1,787 publicly traded companies classified under the food processing industry by Refinitiv's sector definitions. Firms lacking R&D expenditure data were excluded, resulting in 422 firms. To maintain a focus on sustainability dimensions, firms without an E score were also removed, yielding a subsample of 93 companies. All remaining firms had complete scores for E, S, G, CSR, and R&D expenditures for the year 2023. Finally, to ensure the relevance of findings for global health and sustainability debates, firms were further screened based on their international presence. Only the companies either identified as MNC, or with verifiable export activity were retained. The classification was based on information provided in official company websites and annual reports. As a result, three firms (Helixmith Co Ltd, Anjoy Foods Group Co Ltd, and China Yurun Food Group Ltd) were excluded, reducing the final sample size to 90. Supplementary material-1 presents the full list of firms.

The complementary examination includes cases from the final sample, using firm-level data on MC, R&D, and ESG performance. Nestlé and Danone were selected as global leaders with high ESG ratings and substantial R&D investment. BRF, on the other hand, was chosen for its strong sustainability scores (even higher CSR than Nestlé) but comparatively lower MC and R&D, representing firms with limited scale despite strong sustainability signaling.

Variables and data transformation

The dataset includes standardized indicators for R&D expenditure (dependent variable), ESG sub-scores and CSR (independent variables), and MC (control variable).

R&D expenditure (RQ_1)

R&D expenditure (reported in USD thousands) was included to measure firms' innovation behavior. In the sustainability context, R&D serves as a concrete indicator of strategic commitment to developing technologies, processes, or products that address environmental and social challenges. In the food processing sector, it plays a pivotal role in reformulating healthier products and reducing environmental impact [19, 103].

E, S, G, and CSR scores (RQ_1)

The analysis examines the E, S, and G components individually. The focus areas for each subcomponent are as follows [32]:

E: Emissions, resource use, and environmental innovation.

S: Workforce practices, community engagement, and product responsibility.

G: Board composition, transparency, and shareholder rights.

Prior research has emphasized that ESG subcomponents may exert distinct and even divergent effects on firm behavior [9]. Therefore, using an overall ESG index could have obscured such relationships by averaging out positive and negative effects across pillars.

The analysis also includes a separate CSR Strategy score from Refinitiv Eikon. Although this score is technically categorized under G, it specifically reflects the integration of environmental and social concerns into company strategy and public disclosures [29].

Supplementary material-2 presents a comprehensive breakdown of Refinitiv Eikon's ESG scoring methodology, along with its comparison to other major institutions.

Market capitalization (RQ_1)

MC enables cross-country comparability by reflecting market-based valuation and being independent of accounting conventions that vary across jurisdictions. It signals a firm's underlying economic strength more accurately than alternative size indicators that may portray a company as larger than its actual economic capacity [104, 105]. Subsequently, MC allows the model to isolate firm-level structural effects in the relationship between sustainability metrics and R&D investment.

In addition to its primary rationale, the literature also associates MC with both firm capacity and visibility [12, 104, 105]. While firm size provides the financial and organizational resources necessary for innovation [53–56], visibility increases external scrutiny and reputational pressures that tend to amplify ESG engagement [9, 12, 27]. Although the model does not test visibility directly, acknowledging this literature supports viewing MC as a more relevant proxy than other measures.

Variables for RQ_2 (CSR as dependent, E and S as independents)

The CSR score is modeled as a dependent variable, regressed on E and S scores to evaluate whether firms' sustainability communication aligns more closely with one dimension over the other. It helps detect selective alignment, such as firms may emphasize certain ESG elements (e.g., environmental initiatives) while underperforming or underreporting in others (e.g., social domains). Therefore, this design supports the assessment of partial strategic decoupling, signaling targeted legitimacy strategies rather than integrated sustainability efforts.

Table 1 Variables and descriptions (RQ_1 Models)

Variable	Role	Transformation	Description
log_RD	Dependent	$\log_{10}(RD+1)$	R&D expenditure (Innovation Proxy)
log_MC	Control	$\log_{10}(MC+1)$	Market capitalization (firm size)
E	Independent	None	Environmental performance
S	Independent	None	Social performance
G	Independent	None	Governance performance
CSR	Independent	None	CSR communication/ disclosure

Data transformation

Descriptive statistics and normality tests revealed substantial right skewness in both R&D expenditure and MC. To maintain the reliability of regression estimates, both variables were log-transformed by applying the following formulas [103]:

$$\log\_\mathrm{RD} = \log_{10}(\mathrm{R\&D}+1) \tag{1}$$

$$\log\_\mathrm{MC} = \log_{10}(\mathrm{MC}+1) \tag{2}$$

Model development and analysis

RQ_1: to what extent are ESG and CSR scores aligned with R&D investment?

The study conducted a hierarchical multiple linear regression to examine whether ESG sub-components and CSR explain variance in R&D expenditure (log-transformed) beyond firm size.

Model 1-A: Log-transformed Market Capitalization (log_MC) was included as a control variable.

Model 1-B: E, S, G and CSR scores were added to assess their explanatory power.

$$Log(RD_i) = \beta_0 + \beta_1 LOG(MC_i) + \varepsilon_i \tag{3}$$

$$\begin{aligned} Log(RD_i) = {} & \beta_0 + \beta_1 LOG(MC_i) + \beta_2 E_i \\ & + \beta_3 S_i + \beta_4 G_i + \beta_5 CSR_i + \varepsilon_i \end{aligned} \tag{4}$$

Where:

$Log(RD_i)$: Log-transformed R&D expenditure of firm.

E_i, S_i, G_i, CSR_i: ESG sub-scores and CSR performance.

$LOG\,(MC_i)$: Log-transformed market capitalization.

ε_i: Error Term.

Table 1 provides an overview for the variables of RQ_1 models. The G score was retained based on its theoretical relevance to strategic decision-making processes, particularly regarding resource allocation for innovation [106, 107]. Although the CSR Strategy score is technically embedded within the G pillar in Refinitiv's framework, it represents only a minor portion (approximately 13%) [29]. Also, VIF values were checked to verify the absence of multicollinearity (see Table 7).

RQ_2: is CSR performance associated with environmental and social performance?

To test RQ_2, a multiple linear regression was conducted with the CSR score as the dependent variable and E and S scores as independents. The G score was excluded based on theoretical and empirical grounds, as governance indicators typically reflect structural and compliance-oriented attributes rather than substantive sustainability engagement [9, 108].

$$CSR_i = \beta_0 + \beta_1 E_i + \beta_2 S_i + \varepsilon_i \quad (5)$$

The model tests whether CSR communication reflects actual environmental and social performance to provide deeper insight into the Model 1-A and 1-B results.

Table 2 presents the variables of Model 2-A for RQ_2. Although the literature widely suggests that CSR communication is grounded in environmental and social performance, some studies highlight a misalignment between these metrics, indicating selective emphasis in firms' disclosure practices [109–111].

Supplementary tests

To further assess potential strategic decoupling between CSR and core sustainability practices, two additional simple linear regression models were estimated. The supplementary tests reverse the analytical direction, treating E and S scores as dependent variables and CSR as the sole predictor. The aim here is to explore whether CSR disclosures predict actual performance in either the environmental or social domain when analyzed in isolation.

$$E_i = \beta_0 + \beta_1 CSR_i + \varepsilon_i \quad (6)$$

$$S_i = \beta_0 + \beta_1 CSR_i + \varepsilon_i \quad (7)$$

All models were tested for classical linear regression assumptions, and effect estimates are reported in the Results section.

Table 2 Variable roles and descriptions (Model 2-A)

Variable	Role	Description
CSR	Dependent	CSR performance
E	Independent	Environmental performance
S	Independent	Social performance

Results

The analysis follows three steps. First, hierarchical regression models assess whether E, S, G and CSR scores are associated with R&D investment, controlling for firm size (RQ_1). Second, a multiple regression model tests the relationship between CSR score and its potential foundations, E and S performance. Furthermore, supplementary simple linear regressions examine whether CSR performance independently predicts E or S scores, offering additional insight into the degree of alignment across sustainability domains (RQ_2). Third, selected firm-level cases further strengthen the interpretation of these research questions, contextualizing the statistical patterns and offering practical insight into how sustainability-innovation dynamics appear in real-world contexts.

Descriptive statistics and normality assessment

Descriptive statistics, correlation matrices, and diagnostic indicators such as multicollinearity, residual distribution, and explained variance are also reported to validate model assumptions.

Table 3 outlines the key descriptive statistics, indicating a moderate ESG performance and wider dispersion in CSR. It reflects variability in firms' sustainability engagement. RD and MC exhibited extreme right-skewness in their raw form. To address this, both variables were $\log_{10}$-transformed (log_RD and log_MC), substantially improving distributional symmetry [95]. The resulting skewness and kurtosis values fell within acceptable thresholds for normality [112].

Correlation analysis

Table 4 displays the correlation results. The E and S scores are highly correlated ($r = .859$, $p < .01$), suggesting

Table 3 Descriptive statistics with skewness and kurtosis values

			Skewness		Kurtosis	
	Mean	Std Dev	Statistic	Std Error	Statistic	Std Error
E	54.465	26.034	−0.319	0.254	−0.885	0.503
S	51.734	25.938	0.026	0.254	-1.019	0.503
G	55.006	19.187	−0.263	0.254	−0.722	0.503
CSR	47.853	28.251	−0.023	0.254	-1.051	0.503
RD*	63012.839	223089.357	7.428	0.254	61.465	0.503
MC*	9487823.601	29636162.405	7.384	0.254	61.207	0.503
Log_{10}(RD + 1)	6.988	0.901	−0.286	0.254	0.116	0.503
Log_{10}(MC + 1)	9.320	0.814	−0.587	0.254	1.556	0.503

*Mean values are in USD Thousands

Table 4 Correlations

Variables	E	S	G	CSR	Log_RD	Log_MC
E	1	0.859**	0.156	0.695**	0.485**	0.537**
S	0.859**	1	0.173	0.671**	0.377**	0.477**
G	0.156	0.173	1	0.236*	0.200	0.326**
CSR	0.695**	0.671**	0.236*	1	0.385**	0.455**
Log_RD	0.485**	0.377**	0.200	0.385**	1	0.748**
Log_MC	0.537**	0.477**	0.326**	0.455**	0.748**	1

Note: $p < .05$ (*), $p < .01$ (**); $N = 90$ for all correlations

Table 5 Model summary for hierarchical regression models (RQ_1)

Model*	*R*	*R* Sq	Adjusted *R* Square	Std Error of the Estimate	Change Statistics					Durbin-Watson
					R Sq Change	F Change	df1	df2	Sig F Change	
1-A	0.748	0.560	0.555	0.60197	0.560	111.824	1	88	0.000	
1-B	0.762	0.581	0.556	0.60115	0.021	1.060	4	84	0.382	1.282

*Dependent variable = log_RD; Model 1-A predictors: log_MC; Model 1-B predictors: log_MC, E, S, G, CSR

Table 6 ANOVA results for regression models (RQ_1)

	Sum of Squares	df	Mean Square	F	Sig	Sum of Squares
1	Regression	40.521	1	40.521	111.824	.000[b]
	Residual	31.888	88	0.362		
	Total	72.409	89			
2	Regression	42.053	5	8.411	23.274	.000[c]
	Residual	30.356	84	0.361		
	Total	72.409	89			

*Dependent variable: log_RD; Model 1-A predictors: log_MC; Model 1-B predictors: log_MC, E, S, G, CSR;

$p < .001$ (two-tailed)

that firms with strong environmental performance tend to also perform well on social dimensions.

The CSR strategy score shows strong positive correlations with both E and S scores ($r = .695$ and $r = .671$, respectively; $p < .01$), indicating that firms with higher CSR scores also tend to exhibit stronger environmental and social performance.

The G score is weakly correlated with other variables, showing only a modest association with CSR ($r = .236$; $p < .05$) and no significant correlation with innovation investment ($r = .200$; $p > .05$). This limited association further supports the decision to exclude G from the RQ_2 model, as its structural and compliance orientation may not capture substantive sustainability engagement [9].

The log-transformed R&D expenditure (log_RD) is positively associated with E ($r = .485$; $p < .01$), S ($r = .377$; $p < .01$), and CSR ($r = .385$; $p < .01$), indicating that innovation investment tends to be higher in firms with stronger sustainability performance and disclosures.

The strongest correlation in the matrix is between log_RD and log_MC ($r = .748$; $p < .01$), reinforcing the importance of controlling for firm size in subsequent regression analyses.

No correlation exceeds the multicollinearity concern threshold ($r > .90$), supporting the appropriateness of including these predictors in regression models. In addition, Variance Inflation Factor (VIF) values presented in the regression diagnostics confirm that collinearity remains within acceptable bounds.

Regression analysis for RQ_1 (sustainability variables and Innovation)

To address RQ_1, whether sustainability performance indicators are associated with R&D investment, hierarchical multiple regression analysis was conducted. This model structure allows the incremental contribution of sustainability-related variables to be assessed after accounting for firm size.

Table 5 summarizes the hierarchical regression models for RQ_1 (Model 1-A and Model 1-B) as explained below:

Model 1-A: Log-transformed MC (log_MC) was entered as the sole predictor to account for the effect of firm size. The model explained 56.0% of the variance in R&D expenditure (log_RD) ($R^2 = 0.560$; Adjusted $R^2 = 0.555$; $p < .001$) with a strong and statistically significant coefficient ($\beta = 0.737$; $p < .001$).

Model 1-B: E, S, G, and CSR scores were added as independent variables to evaluate their incremental contribution. While the model remained statistically significant overall ($F = 23.274$; $p < .001$), the change in R^2 was small and non-significant ($\Delta R^2 = 0.021$; $p = .382$), indicating that the addition of sustainability indicators did

Table 7 Coefficients and collinearity diagnostics (RQ_1)

Model*	Coefficients			t	Sig	Collinearity Statistics		
	Unstandardized		Standardized					
	B	Std Error	Beta				Tolerence	VIF
1-A	(Constant)	−0.734	0.733		-1.001	0.320		
	Log_MC	0.829	0.078	0.748	10.575	0.000	1.000	1.000
1-B	(Constant)	−0.329	0.800		−0.411	0.682		
	Log_MC	0.776	0.097	0.701	7.981	0.000	0.647	1.546
	E	0.009	0.005	0.269	1.786	0.078	0.220	4.539
	S	−0.007	0.005	−0.193	-1.369	0.175	0.250	3.995
	G	−0.002	0.004	−0.041	−0.546	0.587	0.873	1.146
	CSR	0.001	0.003	0.018	0.180	0.858	0.478	2.091

*Dependent Variable: Log_RD

Table 8 Residuals statistics (RQ_1)

Residuals*	Min	Max	Mean	Std Dev
Predicted Value	4.5709	8.6656	6.9887	0.68739
Residual	-2.06718	1.26466	0.00000	0.58402
Std. Predicted Value	-3.517	2.439	0.000	1.000
Std. Residual	-3.439	2.104	0.000	0.972

*Dependent Variable: Log_RD

not meaningfully enhance the model's predictive power beyond firm size.

Table 6 reports the ANOVA results, confirming both models are statistically significant (F = 111.824; $p < .001$ for Model 1-A; F = 23.274; $p < .001$ for Model 1-B). However, the added sustainability variables did not significantly improve the model fit, reinforcing the dominant role of firm size.

As shown in Table 7, the coefficients and collinearity diagnostics provide further evidence on the relationships tested in RQ_1. In Model 1-A, log_MC is a highly significant predictor of R&D expenditure (β = 0.748; $p < .001$), reinforcing the substantial role of firm size in shaping innovation capacity. The model exhibits no multicollinearity (VIF = 1.000), confirming the stability of this single-predictor model.

In Model 1-B, log_MC remains significant (β = 0.701; $p < .001$). Among the added predictors:

- The E score showed a positive but marginally non-significant association with R&D (β = 0.269; $p = .078$), suggesting a potential but inconclusive link.
- The S and G scores had negative, non-significant effects ($p = .175$ and $p = .587$, respectively).
- The CSR strategy score exhibited a statistically and practically negligible effect (β = 0.018; $p = .858$).

All VIF values are below the commonly accepted threshold of 5, indicating that multicollinearity is not a concern, including for CSR (VIFs < 2.1) [113, 114]. The relatively higher VIFs for E and S (4.5 and 4.0, respectively) likely stem from their strong intercorrelation ($r = .859$), as also noted by [9], but still remain within acceptable bounds.

Table 8 presents the residual statistics associated with the hierarchical regression models. Residual diagnostics supported overall model validity. Predicted values showed no signs of skewness or heteroscedasticity. One observation (BRF SA) exhibited a standardized residual slightly beyond the ± 3 threshold (-3.49) [113]. Further examination confirmed that this case had low Cook's distance (0.098) and leverage (0.034), indicating minimal influence on the model. When excluded, the residual range normalized, while model coefficients and significance levels remained stable. Given the localized and non-distorting nature of this outlier, the case was retained to preserve the full sample size and ensure comparability across models.

The findings are consistent with prior research indicating that larger firms tend to invest more in innovation due to greater capacity [53–56]. However, the addition of sustainability indicators did not meaningfully enhance the model's predictive power beyond firm size, suggesting a potential strategic decoupling between sustainability disclosure and innovation investment [69, 89–92].

Regression analysis for RQ_2 (envirionmental, social and CSR scores)

While the first research question addresses the extent of alignment between sustainability signaling and innovation investment, it remains unclear whether these signals are internally coherent. CSR is often assumed to reflect a firm's environmental and social priorities, yet this alignment is underexplored [115–117]. Therefore, the second research question examines whether these domains are interrelated or whether a disconnect exists among them, suggesting either symbolic use of these metrics or structural inconsistencies in how sustainability performance is disclosed. This distinction expands the scope of strategic decoupling, not only between communication and action, but also within the symbolic structures of sustainability reporting themselves.

Table 9 Model 2-A summary for regression predicting CSR performance (RQ_2)

Model*	*R*	*R* Square	Adjusted *R* Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig F Change	
2-A	0.710	0.504	0.493	20.1180	0.504	44.257	2	87	0.000	2.234

*Dependent Variable: CSR; Predictors: (Constant), S, E

Table 10 Regression ANOVA results (RQ_2)

Model*		Sum of Squares	df	Mean Square	F	Sig
2-A	Regression	35825.171	2	17912.585	44.257	.000[b]
	Residual	35212.166	87	404.738		
	Total	71037.337	89			

*Dependent Variable: CSR; Predictors: (Constant), S, E

Table 11 Coefficients and collinearity diagnostics (RQ_2)

Model*		Coefficients			t	Sig	Collinearity Statistics	
		Unstandardized		Standardized				
		B	Std Error	Beta			Tolerence	VIF
2-A	(Constant)	5.189	5.007		1.036	0.303		
	E	0.492	0.160	0.453	3.069	0.003	0.261	3.828
	S	0.307	0.161	0.282	1.908	0.060	0.261	3.828

*Dependent Variable: CSR

Table 12 Residuals statistics (RQ_2)

Residuals*	Min	Max	Mean	Std Dev
Predicted Value	7.970	81,479	47.853	20.063
Residual	-52.124	43.780	−0.000	19.890
Std. Predicted Value	-1.988	1.676	0.000	1.000
Std. Residual	-2.591	2.176	0.000	0.989

*Dependent Variable: CSR

To address RQ_2, which examines the alignment between CSR performance and firms' actual environmental and social performance, a multiple linear regression model was conducted with CSR score as the dependent variable and E and S scores as predictors. The G score was not included due to conceptual reasoning and prior empirical evidence highlighting its limited relevance in capturing substantive sustainability engagement [9, 29].

Table 9 outlines the regression model predicting CSR performance. The model explained a substantial proportion of the variance in CSR scores (R^2 = 0.504; Adjusted R^2 = 0.493) and was statistically significant ($F(2, 87) = 44.257$; $p < .001$). The Durbin-Watson statistic (2.234) indicated no autocorrelation and supporting the assumption of independent residuals [113, 114].

Table 10 summarizes the ANOVA results for the regression model. Its statistical significance confirms that E and S scores jointly explain a meaningful proportion of the variation in CSR scores. Therefore, firms with higher performance in environmental and social domains tend to report stronger CSR engagement.

Table 11 reports the coefficients and collinearity diagnostics for the regression model predicting CSR performance. The E score was a statistically significant predictor of CSR (β = 0.453; p = .003), while the S score approached significance (β = 0.282; p = .060). The results suggest partial alignment between CSR strategy disclosures and underlying sustainability performance, with a stronger link to environmental efforts. Furthermore, multicollinearity diagnostics indicate interdependency between the predictors (VIF = 3.828), reflecting their high correlation (r = .859), as also noted in prior research [9].

Table 12 presents the residual statistics for the regression model. Standardized residuals fell between the ± 3 cutoff for normality. Less than 5% of residuals exceeded ± 2.0. Thus, the residuals exhibited an approximately normal distribution with a mean near zero and a standard deviation close to one, further confirming the absence of problematic outliers and supporting model robustness [113, 114].

Supplementary tests: directional insights into CSR alignment

To further explore the potential strategic decoupling between CSR disclosures and actual sustainability performance, two supplementary simple linear regression models were estimated. These models tested whether CSR strategy scores independently predict E and S performance. The aim was to assess whether CSR engagement demonstrates balanced alignment across sustainability dimensions or reflects selective emphasis on certain domains.

Table 13 CSR predicting environmental performance (E)

Model*	Coefficients			t	Sig	Collinearity Statistics	
	Unstandardized		Standardized				
	B	Std Err	Beta			Tolerence	VIF
(Constant)	23.801	3.917		6.076	0.000		
CSR	0.641	0.071	0.695	9.077	0.000	1.000	1.000

*Dependent Variable: E

Table 14 CSR predicting social score (S)

Model*	Coefficients			t	Sig	Collinearity Statistics	
	Unstandardized		Standardized				
	B	Std Err	Beta			Tolerence	VIF
(Constant)	22.240	4.025		5.525	0.000		
CSR	0.616	0.073	0.671	8.497	0.000	1.000	1.000

*Dependent Variable: S

Table 13 shows the relationship between CSR score and environmental performance (E). The analysis was statistically significant (R^2 = 0.483; F(1, 88) = 82.38; $p < .001$), with CSR emerging as a strong predictor ($\beta = 0.695$; $p < .001$). Diagnostic checks indicated no issues with multicollinearity or residual patterns.

Table 14 presents the relationship between CSR score and social performance (S). The model was statistically significant (R^2 = 0.451; F(1, 88) = 72.19; $p < .001$), with CSR emerging as a strong predictor ($\beta = 0.671$; $p < .001$). Diagnostic checks revealed no concerns regarding multicollinearity or residual patterns.

The results for RQ_2 indicate that environmental and social scores significantly explain variation in CSR performance, with environmental metrics contributing more strongly. Supplementary regressions confirmed CSR as a significant predictor of both E and S scores, suggesting statistical alignment across models. All residual and multicollinearity diagnostics remained within acceptable thresholds.

Firm-level insights into sustainability-innovation decoupling

The study applies a targeted case-selection strategy to illustrate how the observed sustainability-innovation gap manifests in practice. Nestlé, Danone, and BRF demonstrate forms of strategic decoupling between reported commitments and substantive innovation outcomes.

Nestlé:

Nestlé is among the global leaders across sustainability metrics, MC, and R&D investment. The company invested approximately USD 1.97 billion in R&D across 23 technology centers, emphasizing AI-powered recipe optimization, plant-based innovation, and sustainable packaging in 2023. Its public reports underscore commitments to regenerative agriculture, carbon neutrality, and health-oriented products [118, 119].

However, substantial strategic decoupling is evident upon closer scrutiny. ShareAction analysts note that Nestlé counts plain coffee and infant foods as "healthy," inflating its figures. Independent assessments estimate that only around 25% of sales meet recognized nutrient profiling standards. Nestlé's "nutritious sales" target largely tracks overall revenue, meaning less healthy sales to grow unchecked, a structural decoupling between targets and portfolio transformation [120].

Moreover, Nestlé's AI systems optimize recipes for consumer appeal and market responsiveness, rather than health-first innovation [121]. Investigations found that Cerelac and Nido products in low-income countries frequently contain added sugar (while their European/Swiss equivalents are often sugar-free), directly contradicting WHO guidance advising no added sugar for children under three [122, 123]. This disparity underscores that while Nestlé's R&D enables healthier formulations, their application often depends on local regulatory pressure rather than the voluntary commitment they project in their public image. In relation to regulatory contexts, research notes that Nestlé employs discursive and lobbying strategies that shape public health policy in its favor, sustaining its advantage despite rising regulatory pressures [124].

Danone:

Danone represents another global leader on all three metrics, emphasizing research and innovation as central to its sustainability agenda with ambitious commitments. The company reports developing low-carbon ingredients and packaging, and advancing reuse models. Research centers in France and the Netherlands coordinate these efforts in collaboration with various stakeholders. The company also reported investments in nutrition and hydration science and claimed that 83.2% of kids' dairy was fortified with vitamins and minerals and 99.3% of toddlers' milk met sugar thresholds [125, 126].

Yet closer analysis reveals partial strategic decoupling between these commitments and actual innovation practices. In 2024, Danone withdrew Nutri-Score labels from several drinkable dairy and plant-based products after algorithm updates downgraded their ratings. NGOs and consumer groups criticized this decision as undermining nutrition transparency and accountability [127, 128]. The company also pursued regulatory pathways to reinforce brand positioning: in 2024, the U.S. FDA allowed a qualified claim that yogurt may reduce type-2 diabetes risk following a petition from Danone, despite limited evidence and no distinction by sugar or fat content [129–131]. Such cases echo historical precedents, with the U.S. FTC and the EFSA sanctioning Danone for misleading health claims [132, 133], and a 2013 marketing campaign in Türkiye condemned for discouraging breastfeeding and misusing WHO and Unicef endorsements [134, 135]. Finally, Danone has faced legal action in France under the duty of vigilance law. In 2023, NGOs sued the company for failing to present a credible plan to reduce plastic packaging, despite high-profile circularity and climate commitments [136]. Consequently, Danone illustrates strategic decoupling, as strong ESG performance and ambitious commitments coexist with practices that prioritize brand positioning over substantive sustainability gains.

BRF:

Despite ESG and CSR scores comparable to Danone and Nestlé, BRF invests far less in R&D, reflecting constraints from its smaller scale and absorptive capacity. The company nonetheless reports initiatives such as recipe reformulation to reduce salt, sugar, and fat, clearer GMO disclosure, and ingredient development like the chicken-liver protein BioActio. Yet, much of its portfolio remains centered on highly processed foods such as ready-to-eat meals and margarines [137], suggesting that R&D is oriented more toward compliance and brand positioning than transformative nutrition or sustainability. Greater detail in the company reports is devoted to operational innovation, including AI models for corn price forecasting and IoT sensors for production efficiency [137, 138].

While BRF also claims 100% certification of animal welfare across poultry and swine slaughter units, the 2024 Business Benchmark on Farm Animal Welfare ranked the company in Tier 4 (on a 1–6 scale, where Tier 1 reflects leadership and Tier 6 the weakest), indicating limited evidence of substantive progress [139]. Adding to reputational challenges, BRF signed a US$111 million leniency agreement with Brazil's Attorney General's Office and Comptroller General in 2022 after federal probes alleged that employees bribed food safety inspectors under Operations Carne Fraca and Trapaça, underscoring governance and compliance vulnerabilities despite subsequent reforms [140, 141]. Taken together, BRF exemplifies compliance-oriented decoupling that limits transformative sustainability innovation.

Overall, the three cases illustrate that high ESG and CSR ratings do not necessarily translate into innovation practices that improve nutrition or environmental outcomes. While the firms differ in scale and market positioning, they share a common pattern of emphasizing legitimacy over transformative innovation, thereby reflecting the broader sustainability-innovation decoupling identified in the quantitative results.

Discussion

This study provides a critical perspective on how sustainability disclosures relate to innovation behavior in the global food processing industry, building on the conflicting literature [18–26]. The present results indicate that innovation is largely shaped by firms' financial and organizational capacities (as proxied by MC), as also noted in previous studies [53–56].

Although the environmental score showed a modest positive coefficient, it fell short of significance ($p = .078$). The result points that environmental engagement may influence innovation only to a limited degree, without a consistent way across the sample. Moreover, the disconnection of S, G, and CSR indicators from R&D further raises concerns regarding the integration of sustainability into innovation strategies.

The analysis of RQ_2 adds further depth to this narrative. CSR was moderately associated with environmental performance, whereas its association with social indicators did not reach significance. The asymmetry points to a selective emphasis on more measurable or externally audited dimensions of sustainability, as also observed in earlier research on corporate sustainability disclosures [22, 142]. It echoes the literature on strategic decoupling, which argues that sustainability metrics often function more as tools of legitimacy than as mechanisms that integrate sustainability into innovation strategies [28, 66, 89, 90].

The qualitative review of Nestlé, Danone, and BRF further supports the statistical analyses. Even among companies with substantial R&D budgets, innovation activities appear prioritize market responsiveness rather than sustainability transformation, and the persistence of unsustainable practices, including lobbying activities, ethical controversies, and superficial regulatory compliance, poses significant risks to environmental and public health. The qualitative insights align with broader patterns observed in the commercial determinants of health literature, where firms often exhibit high CSR visibility while continuing practices that undermine public health, such as marketing ultra-processed foods to children, misleading branding, or prioritizing sugary products [2, 23, 24]. For example, studies have shown that firms like

Nestlé and McDonald's have emphasized sustainability in their reporting while simultaneously facing criticism for neglecting the nutritional quality of their products or employing aggressive marketing strategies targeting vulnerable consumer segments [25, 143].

Taken together, the findings reveal a strategic ambivalence in the alignment between sustainability communication and innovation strategy. While ESG and CSR indicators are undoubtedly important tools for signaling corporate responsibility [65, 67], their role as drivers of sustainable innovation behavior in the food processing industry appears limited. This situation echoes broader concerns raised in studies on legitimacy theory and strategic decoupling, reinforcing the conclusion that sustainability engagement is more responsive to reputational management than to internal transformation [6, 28, 62, 75, 86].

Theoretical implications

At first glance, stakeholder theory offers a reassuring explanation: Firms respond to societal expectations because their long-term survival depends on it. Regulators tighten policies, consumers ask tougher questions, and investors increasingly prioritize sustainability metrics. In theory, firms that listen closely and act accordingly will thrive [63–65]. Indeed, recent literature points to firms with strong ESG or CSR profiles investing more in sustainable innovation, particularly when such efforts align with stakeholder interests or reputational concerns [18–20]. Large corporations, in particular, can leverage established stakeholder trust, superior organizational capabilities, and access to financing to convert these expectations into innovation investments [20].

However, the findings of this study reveal a more conflicted picture. Despite the prominence of CSR and ESG rhetoric, actual integration into innovation strategies appears inconsistent, if not entirely absent in some cases. One might argue this reflects limited capacity. After all, not every firm can overhaul its supply chain or launch green R&D overnight. But others, especially large multinational corporations, do have the resources, and still opt for less substantive responses, as seen in the recent studies [25, 143]. This raises a deeper concern: Are firms engaging in meaningful transformation, or simply reinforcing their image?

Legitimacy theory helps reframe this dilemma. Firms operating in sensitive industries, like food processing, are under constant scrutiny. In such contexts, sustainability becomes a shield, driven more by isomorphic pressures to conform to global reporting norms rather than meaningful strategic integration [7, 28, 62, 65, 75, 86]. The observed asymmetry in Model 2-A, with stronger environmental (E) alignment but suppressed social (S) contributions, reinforces this view. Companies prioritize more visible, auditable, and reportable aspects, such as emissions disclosures or recyclable packaging. Meanwhile, less tangible but arguably more socially urgent areas such as labor equity, public health impacts, and nutritional value often remain peripheral, likely due to their limited visibility or lack of short-term quantifiability [8, 21, 22, 142, 144, 145]. In food processing, as corporate strategies directly shape consumption patterns and health outcomes, ethical concerns over firms' role in diet-related diseases arise [5, 6].

The concept of strategic decoupling further explains this divergence by highlighting the disconnect between formal disclosures and operational realities [89]. Companies increasingly adopt CSR and ESG frameworks in their public disclosures while maintaining business-as-usual internally. The reflections of this disconnect are visible in ongoing contradictions, as ultra-processed foods remain aggressively marketed to children by companies with glowing CSR pages [2, 25]. Similarly, environmental harms related to packaging and supply chains remain widespread among leading firms like Coca-Cola Company and PepsiCo. While disclosures emphasize emissions reduction, the companies pay less attention to plastic waste and resource depletion across their supply chains [143]. These symbolic performances often fall short of addressing the deeper, systemic inequities that shape food access, health outcomes, and consumption patterns, particularly for low-income communities. Here, commercial strategies continue to promote high-calorie, nutrient-poor products, deepening the burden of non-communicable diseases and widening public health disparities [2, 24, 143, 146]. Subsequently, if stakeholder theory suggests what firms ought to do, and legitimacy theory explains what they feel compelled to show, then strategic decoupling reminds us of what remains undone.

Practical and policy implications

The observed strategic decoupling between sustainability reporting and core business practices provides implications for firms, regulators, and broader public stakeholders seeking to advance sustainability in the global food processing sector. For corporate managers, the disconnect between disclosures and innovation strategies poses a clear risk. One possible explanation is the emergence of organizational silos, where sustainability is typically managed by communications or compliance departments in isolation [147, 148]. Innovation ecosystems, where talent, academic partnerships, and R&D investments remain weakly connected to broader transformation strategies further reinforce this fragmentation [50, 149]. In contrast, companies that embed sustainability values directly into innovation may strengthen both public trust and long-term resilience, as organizational structures influence the integration of technological innovation [150].

Emerging Food Processing 4.0 platforms and technologies such as HPP or PAW could serve as examples of sustainable implementation [46, 47]. Emerging technologies like PAW and Food Processing 4.0 platforms could be pathways toward sustainable implementation [46, 47].

On the environmental front, clarity and consistency are still lacking. Definitions of ESG and CSR vary widely across jurisdictions, giving firms room to comply superficially without true accountability [6, 68], such as pressing issues such as plastic waste and water stress remain under-addressed despite cosmetic sustainability reporting [143, 136]. Policies like the EU Taxonomy are a step forward, tying disclosures to science-based benchmarks [151]. To reinforce policy coherence, complementary metrics, such as green venture capital flows and environmental technology licensing, can serve as early indicators of innovation commitment and market translation [152].

From a public health perspective, unethical marketing practices remain a key driver of the commercial determinants of health. Yet, massive capital continues to flow into the global breast-milk substitute industry, where lobbying and research manipulation are routinely used to protect profit-maximizing interests [153]. Such practices, exemplified by Danone's 2013 Türkiye campaign, exploit public health vulnerabilities, particularly in emerging and low-income contexts. As this dynamic will likely remain a major barrier to achieving transformative and sustainable change, a broader structural question arises: can these food processing companies genuinely operate within an economy that sustains public health, equity, and environmental integrity?

Within the current market architecture, profitability depends on high-volume sales of low-cost, nutrient-poor products, while financial and political networks continue to shape policy agendas. These conditions suggest that shareholder interests and public well-being remain structurally decoupled. As a result, commercial determinants of health may arise as an inherent tendency of the sector itself [153–156].

Several pathways can address such structural contradiction, including mission-oriented innovation policies [157] and polycentric governance frameworks that combine state, civil, and scientific oversight [158, 159]. Studies also suggest developing disclosure frameworks that include more health-oriented metrics and call on policymakers to track measurable outcomes, such as reduced use of harmful additives, improved nutrient density, and increased access to safe, affordable alternatives, rather than the number of CSR and reformulation initiatives [6, 24]. Another crucial step in combatting the commercial determinants of health is empowering consumers through education and access to transparent information. Awareness and affordability should accompany policy efforts that reshape the food environment and remove barriers to healthy choices [160, 161]. Partial transformations through fiscal and labeling regulations have measurably reduced harmful product consumption. In Chile, front-of-pack warning labels reduced sugary drink sales by over 20%. Taxation, on the other hand, prompted widespread product reformulation and increased consumer awareness in Mexico and the UK [162–164]. Overall, genuine reconciliation requires redefining corporate value creation, stakeholder intervention, and cultivating more capable consumers, so that sustainable contributions can be prioritized over short-term financial returns.

Limitations and future research

The cross-sectional nature of the data restricts causal interpretations, and future work should employ longitudinal designs to examine whether the observed patterns persist or evolve. While R&D expenditure is a widely used proxy for innovation input, it does not directly reveal the outcomes or orientation of such efforts. For example, patents, process improvements, or product-level differentiation may be embedded within R&D budgets but cannot be disaggregated in the present dataset. Future research could combine expenditure data with output indicators to obtain a fuller view of eco-innovation.

While the three firm-level vignettes enhance interpretive depth, they remain illustrative rather than comprehensive. Broader qualitative inquiry, such as interviews with managers or multi-case comparisons, could offer deeper insight into the mechanisms underlying sustainability-innovation decoupling.

Another limitation relates to the measurement of firm size, as every indicator has strengths and weaknesses, and no single measure can fully capture its multidimensional characteristics [104]. MC was chosen for its cross-country comparability and theoretical relevance, yet its volatility and sensitivity to investor sentiment make it an imperfect proxy. However, alternative financial indicators present comparable or greater challenges: profits may decline due to reinvestment, revenues can obscure margins and fluctuate with commodity cycles, and equity or asset-based measures are constrained by accounting conventions that constrain global comparison [105]. Future research could employ more comprehensive models combining multiple indicators, including both financial and non-financial measures.

Finally, data providers such as Refinitiv, MSCI, Sustainalytics, and Bloomberg apply different weighting schemes and disclosure adjustments, which may bias cross-firm comparisons. These methodological differences could have influenced the results, and future research may test robustness with alternative ESG datasets.

Conclusion

This study highlights the persistent misalignment between sustainability disclosures and innovation strategies in the global food processing sector. Despite the widespread adoption of ESG and CSR frameworks, their integration into innovation remains weak, raising the risk of strategic decoupling where sustainability appears in disclosures rather than in practice.

The findings are especially relevant for public health, as ultra-processed foods continue to displace nutrient-dense alternatives and exacerbate health disparities, while environmental challenges such as plastic waste and water stress remain neglected.

Overall, the study underscores that sustainability should move beyond disclosure and communication, and be embedded more substantively into corporate strategy and innovation. Without this shift, the gap between what firms promise and what they deliver is likely to persist.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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