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Supply chains (Scope 3) toward sustainable food systems: An analysis of food & beverage processing corporate greenhouse gas emissions disclosure

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ABSTRACT

To align business activities with the Paris Agreement goal to limit global warming to 1.5°, companies may disclose and set targets to mitigate their emissions. The global food system contributes up to 37% of total annual emissions. Major food & beverage processing companies heavily contribute to food system emissions through their supply chains. Despite this, sector-specific analysis of the status and quality of scope 3 emissions for food & beverage processing companies is lacking. Using 2018 CDP data to build a sample of 153 companies, the authors describe the state of voluntary disclosure, particularly for scope 3, for food & beverage processing companies. Further, the paper investigated the effect of emissions performance, national environmental policy, international negotiation group, and primary activity on scope 3 disclosure. It also examined the effect of primary activity, scope 3 disclosure, and national environmental policy and international negotiation group on direct- and energy-related emissions performance. The authors found scope 3 disclosure in the food & beverage processing sector was incomplete and inconsistent. The 2018 Environmental Performance Index score and the international negotiating group of a company's headquarter country were significant predictors of scope 3 disclosure by category. Firm size (by revenue) was the only significant predictor of direct and energy-related (scopes 1 and 2) emissions, but was not correlated with improved emissions performance. The authors concluded with a set of recommendations to improve the availability and transparency of scope 3 emissions data, and invited further research into sector-specific scope 3 disclosure, performance, effect of firm size and climate policy at the national and international levels.

1. Introduction

In 2018, global greenhouse gas (GHG) emissions reached a record high of 37,100 MT CO_2eq (Harvey and Gronewold, 2019). The food system contributes an estimated 21–37% of annual GHG emissions (Mbow et al., 2019; Crippa et al., 2021). The vast majority of food system emissions are associated with land use and production (71%), as opposed to distribution, processing, consumption, and end-of-life disposal (29%) (Crippa et al., 2021). Land use and production emissions are directly tied to the supply chain policies of food & beverage processing companies, which have shared responsibility for their embodied emissions (Hertwich and Wood., 2018; Sanderson, 2021).

The international climate treaty, or Paris Agreement, aims to limit global warming to well below 2 °C, and to pursue efforts to limit warming to 1.5 °C. Nonetheless, the world is currently on track to exceed 3 °C of global warming this century, presenting a serious gap between the global emissions curve and Paris goals (United Nations Environment Programme, 2020). The urgency of the climate crisis and the persistent emissions gap underscore the moral and economic imperative of not just national governments, but also the private sector, to align with these goals. Private sector actors have opportunities to improve efficiencies throughout their global supply chain (United Nations Environment Programme, 2020). As of June 2021, 589 businesses had signed a commitment to align their climate targets across all scopes with 1.5C emissions scenarios, increasing the momentum of voluntary corporate climate action (Business Leaders Taking Action., 2021). A first-of-its-kind court decision in the Netherlands holding Shell responsible for its direct and indirect emissions also set a new legal precedent for companies to reduce supply chain emissions (Joselow, 2021). Furthermore, corporate actors in the food, beverage, and agriculture industry have a particularly strong incentive to do so, considering the significant share of global emissions they contribute, coupled with the serious threats they face due to a changing climate (Mbow et al., 2019).

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The first step toward designing an effective emissions reduction plan is to calculate and report a GHG inventory that includes the full extent of supply chain activities. GHG inventories at the firm level are one of multiple carbon accounting forms. Global multi-region input-output analysis (MRIO) databases may be used to analyze environmental impacts of the food industry by country or region (Kucukvar et al., 2019). Life cycle analysis (LCA) may be used to quantify the impacts of a specific product and guide its re-design to increase sustainability. Considerable advancements have been made in LCA methodologies; firm-level and industry-wide research has been more limited, and the authors aimed to fill this gap by focusing on firm level emissions in the food & beverage processing sector (Meinrenken, 2020).

The GHG Protocol is the most widely used methodology to manage and mitigate corporate-level GHG emissions (Ascui and Lovell, 2011). The GHG Protocol divides a company's emissions into three separate scopes for reporting. Direct emissions from sources owned or controlled by the reporting company fall under scope 1, for example refrigerant leaking from company-owned machinery (Bhatia and Ranganathan, 2004). Indirect emissions that relate to the company's purchase of electricity, steam, heating, and cooling fall under scope 2 (GHG Protocol Agricultural Guidance, 2014). The rest of a company's indirect emissions fall under scope 3, or emissions from supply chain activities (Bhatia et al., 2011). Although scope 3 emissions often comprise the largest proportion of an organization's emissions, existing guidelines fall short of requiring comprehensive reporting (Hertwich and Wood., 2018). In the 2021 Climate Action 100+ Net Zero Company Benchmark, scope 3 disclosure remained a blind spot (Climate action 100+, 2021). Failure to account for scope 3 emissions can result in serious underestimation of a company's climate change impact, and prohibit management from implementing effective mitigation and supply chain resilience strategies (Patchell, 2018). On the other hand, accounting for and disclosing scope 3 emissions can increase corporate accountability and allow consumers to make purchasing decisions with the knowledge of a brand's cost on society and the environment (Sterner et al., 2019).

Once a business calculates its GHG emissions, it may voluntarily disclose those emissions on a reporting platform. The largest and most thorough of these platforms is CDP. CDP requests information from companies on behalf of 515 institutional investor signatories that represent an accumulated $106 trillion in revenue ("What We Do," 2020). Notably, scope 3 emissions are optional to disclose to CDP. Disclosed scope 3 emissions are sub-divided into fifteen reporting categories according to the GHG Protocol Corporate Value Chain Standard (Barrow et al., 2013).

The following subsection of this paper reviews the existing literature on the drivers and determinants of emissions disclosure, the relationship between voluntary emission disclosure and corporate carbon performance, and the challenges of accounting scope 3 emissions and the extent of under-reporting. Subsequently, the research questions and aims of this paper cite specific gaps in the relevant literature.

1.1. Drivers and determinants of emissions disclosure

A multitude of factors determine whether or not companies account and disclose GHG emissions and pursue subsequent climate action. Institutional theory suggests external factors like social and cultural norms, as well as home country legal framework, will shape corporate behavior (Hahn et al., 2015; Amran et al., 2016; Li et al., 2018). Stakeholder theory argues regulation can also increase investor, non-governmental organization (NGO), and consumer pressure on companies to develop climate change responses (Hahn et al., 2015; Pinkse and Busch, 2013). Hickmann (2017) discussed two-way influence, arguing corporate voluntary disclosure regimes may also act as building blocks for future climate policies (Hickmann, 2017). O'Rourke (2014) found companies report emissions to comply with policy, as well as to gain competitive advantage by demonstrating leadership and managing risk (O'Rourke, 2014). In contrast, Damert and Baumgartner (2018) found the stringency of domestic regulation to be irrelevant as a driver of corporate climate action, while consumer pressure and risk management were found to be major determinants (Damert and Baumgartner, 2018). To investigate these theories as applied to food & beverage processing companies for this paper, the authors selected the Environmental Performance Index (EPI), a metric of country-level sustainability that uses 32 indicators to gauge progress against policy targets (Wendling et al., 2018). The EPI is designed as a data-driven global scorecard and tool for governments to address environmental challenges, indicating its appropriateness as a variable to compare the strength of national regulation.

Companies face serious physical and transition risks due to climate change; in response, Sullivan (2017) noted that virtually every company will have to rethink its activities, as well as contribute to reducing emissions (Sullivan, 2017). Risk affects not only individual firms, but also investors and the entire global market. The Paris Agreement is a global, non-binding international governance framework to address climate change at the same scale that it impacts the planet. However, a gap exists in the literature with regard to the impact of international climate negotiations on corporate emissions and disclosure. In response, this paper tests the relationship between headquarter country negotiating group and firms' disclosure and emissions. To enable market-wide financial stability and allow investors to risk manage their assets, Sanderson (2021) wrote companies should assess and transparently disclose all emissions (Sanderson, 2021).

According to Ortas et al. (2015), creating a company-wide GHG inventory allows companies to identify emissions reductions opportunities and set ambitious reduction goals built on strong baseline data (Ortas et al., 2015). Hassan and Romilly (2018) demonstrated a strong association between good environmental performance and strong economic performance, suggesting emissions reductions may yield monetary benefits (Hassan and Romilly, 2018). To maximize firm value, Karim et al. (2021) encouraged managers to provide more carbon-related data and share it with stakeholders (Karim et al., 2021). Because the global economy rewards constant growth, one aspect of strong economic performance could be considered firm size, or revenue. Both Younis and Sundarakani (2019a, 2019b) and Kumar and Firoz (2019) found firm size plays a key role in voluntary environmental disclosure; thus, the authors also tested the effect of firm size on emissions performance and disclosure in this study (Younis and Sundarakani, 2019a; Kumar and Firoz, 2019). Emissions disclosure is one of multiple complementary practices identified by Mahapatra et al. (2021), including lower energy consumption, emissions trading, and risk and opportunity identification, that may be used in pursuit of corporate climate mitigation goals (Mahapatra et al., 2021). While corporate self-regulation is inherently fraught because markets value profit and growth above the environment, well-intentioned business leaders still have the power to promote sustainable policy with far-reaching impacts (Lohmann, 2009).

Supply chain emissions have increased over time as a share of total corporate GHG footprints, which indicates that intermediate producers play a crucial influencing role on emissions (Hertwich and Wood., 2018). Although current scope 3 reporting guidelines are voluntary, Tidy et al. (2016) found companies anticipated legal requirements could be on the way (Tidy et al., 2016). In May 2021, a Dutch court ruled the oil & gas company Shell was obligated to improve its emissions reduction targets across all scopes to align with net-zero by 2050, creating novel legal precedent that could hold companies accountable for scope 3 emissions (Joselow, 2021). Pressure from primary stakeholders such as consumers to see the full cost of their purchase on society may incentivize companies to account for and disclose scope 3 (Sterner et al., 2019; Hsu et al., 2019).

1.2. Voluntary emissions disclosure and corporate carbon performance

The GHG Protocol and CDP (formerly the Carbon Disclosure Project) are two significant enablers of climate change specific corporate reporting. In 2019, over 8361 companies representing over 50% of global market capitalization reported to CDP ("What We Do." 2020.P., 2020).

Studies disagree on whether or not strong environmental disclosure is correlated with strong environmental performance (Hsu et al., 2019). Legitimacy theory predicts poor environmental performers will disclose more to legitimize continuance of business as usual (Clarkson et al., 2011; Cho and Patten, 2007; Mahadeo et al., 2011). Signaling theory predicts strong environmental performers will disclose more to demonstrate leadership and distinguish themselves (Mahapatra et al., 2021; Clarkson et al., 2011; Al-Tuwaijri et al., 2003). Some studies found no significant relationship between disclosure and emissions (Hassan and Romilly, 2018; Jaggi et al., 2011). Discrepancies across the extant literature may result from variance of environmental performance measures and the lack of a temporal dimension in research models (Hassan and Romilly, 2018).

Qian and Schaltegger (2017) described the outside-in management view, which predicts that better disclosure leads to better performance (in line with signaling theory) because data enables managers to make informed decisions (Qian and Schaltegger, 2017). Companies are capable of using disclosure as an "outside-in" opportunity to improve carbon performance; these decarbonizing improvements could save companies money and further reduce damage to society and the environment (Mahapatra et al., 2021; Qian and Schaltegger, 2017). The rationale for full scope 3 accounting is to identify leverage and mitigation points across supply chains (Hsu et al., 2019). Efforts to reduce emissions across scopes 1, 2, and 3 may help companies prioritize mitigation steps, review and revise procurement strategies, and hasten their transition to a true net-zero business mode (Li et al., 2020). When it comes to reducing emissions and saving costs, the usefulness of data and disclosure is only so good as its quality. Li et al. (2018) investigated the likelihood of CDP disclosure and called for further research into disclosure quality (Li et al., 2018).

Launched in 2014, the Science Based Targets Initiative (SBTi) supports the creation of emissions reduction targets aligned with Paris Agreement goals. To establish a Science-Based Target, companies must have their emissions accounting verified according to industry standards. CDP tracks the number of companies reporting SBTs, or intending to report within two years, but does not provide an assessment of progress against disclosed emissions. Giesekam et al. (2021) found a significant difference between the progress toward SBT targets that covered scopes 1 and 2 versus progress toward targets that included scope 3: companies were falling behind on reducing supply chain emissions (Giesekam et al., 2021).

1.3. Challenges of scope 3 reporting and extent of scope 3 under-reporting

According to Bhatia et al. (2011) (Bhatia et al., 2011), "Scope 3 emissions can represent the largest source of emissions for companies and present the most significant opportunities to influence GHG reductions." Reducing emissions in line with the Paris Agreement goals will require scope 3 emissions intensity targets to be 1.8 times more ambitious (Li et al., 2020). However, disclosure of scope 3 emissions is less mature and more limited than that of other scopes (Doda et al., 2016; Sanderson, 2021). Technical limits, high transaction costs, data uncertainty, and the need for unprecedented collaboration across complex value chains combine to make scope 3 data collection for disclosure quite challenging (Patchell, 2018; Huang et al., 2009; Blanco et al., 2016). When it comes to scope 3 categories like business travel that require less external engagement, companies may also be choosing not to pursue alternative low-carbon options (Qian and Schaltegger, 2017). Blanco et al. (2016) found scope 3 disclosure significantly varied by sector (Blanco et al., 2016). Igl and Kellner (2017) cited emissions from the agriculture sector—made up mostly of methane (CH4) and nitrous oxide (N2O)—as particularly uncertain, due to farm-based estimates that are rarely verified (Igl and Kellner, 2017). Bager et al. (2019) stated food-related emissions could increase by as much as 30% in the next thirty years, suggesting an urgent need for sector-specific mitigation strategies (Bager et al., 2019).

Engaging suppliers may be an effective strategy to decarbonize supply chains (Dahlmann and Roehrich, 2019; O'Rourke, 2014), but obtaining emissions data from vendors and customers presents a significant challenge (Li et al., 2020). Furthermore, no existing frameworks are designed to comprehensively capture and benchmark scope 3 emissions (Li et al., 2020), and a plethora of unstandardized metrics prevent comparability across studies (Hassan and Romilly, 2018). In addition to quantitative metrics, CDP scope 3 disclosure includes qualitative comments and descriptive written reports, which Mahapatra et al. (2021) found to be "highly non-uniform and subjective" (Mahapatra et al., 2021). Due to the challenges of supplier engagement, even companies disclosing comprehensive scope 3 data may struggle to translate those efforts into lower emissions by external supply chain partners (Mahapatra et al., 2021). The authors recognize there is shared responsibility for supply chain emissions, and that scope 3 disclosure is part of a suite of tools that may be used to plan and implement effective emissions reductions strategies in partnership with suppliers (Hertwich and Wood., 2018; Sanderson, 2021).

In summary, scope 3 emissions present the largest opportunity for companies to influence emissions reductions, but scope 3 disclosure remains limited in comparison to scopes 1 and 2 and significantly varies by sector (Bhatia et al., 2011; Sanderson, 2021; Blanco et al., 2016). Calculating agricultural emissions is particularly uncertain (Igl and Kellner, 2017). The rationale for accounting and disclosing scope 3 is to identify leverage points along the supply chain for GHG reductions (Hsu et al., 2019). Besides mitigating the harmful impacts of climate change, efforts to reduce emissions may also help companies improve procurement strategies and save costs (Li et al., 2020). Companies, however, will not necessarily act to reduce emissions on their own. Institutional and stakeholder theories suggest home country regulatory frameworks and anticipated legal requirements create direct pressure on companies to take climate action, and encourage investors and NGOs to push for improved corporate behavior (Hahn et al., 2015; Amran et al., 2016; Li et al., 2018; Pinkse and Busch, 2013; Hickmann, 2017). On the basis of the literature review, this paper raises the following questions:

- To what extent are firms providing voluntary emissions disclosure, particularly of scope 3,[1] for the food & beverage processing sector?
- How does emissions intensity,[2] national environmental policy, international climate negotiation group, and primary activity influence scope 3 disclosure?
- How much influence does firm size (revenue), primary activity, scope 3 disclosure, international negotiation group, and national environmental policy have on direct- and energy-related absolute emissions and emissions intensity?

Through the investigation of these questions and subsequent analysis, this paper offers important contributions to the existing literature. First, this paper offers a response to Blanco et al.'s (2016) call for further investigation of sector-specific supply chain emissions by analyzing scope 1, 2, and 3 disclosure by food & beverage processing firms (Blanco et al., 2016). Second, it contributes a novel scoring index for scope 3 qualitative

[1] Scope 3 disclosure refers to self-reported supply chain emissions data, in units of CO2eq, sub-divided into fifteen reporting categories according to the GHG Protocol Corporate Value Chain Standard ("What We Do." 2020.P., 2020). It also refers to supplementary qualitative comments that companies may voluntarily submit along with quantitative emissions data.

[2] To compare emissions performance across firms, it is important to use a ratio of absolute emissions to a product or financial base. Firms with high carbon intensity values may be operating less "carbon-efficiently," producing more GHGs per dollar, than a firm with a lower carbon intensity. This paper defines emissions performance as direct- and energy-related carbon emissions intensity, calculated from the absolute direct and energy-related (scope 1 and 2) emissions and annual revenue (a proxy for firm size). The terms may be used interchangeably throughout the paper.

comments, building on the research of Li et al. (2018) and Mahapatra et al. (2021) by analyzing the *quality* of disclosure and accompanying descriptive information (Li et al., 2018; Mahapatra et al., 2021). Third, in light of Hickmann (2017)'s research relating voluntary disclosure to government regulation, this paper investigates the institutional theory effect of national policy and international negotiation groups on firm level emissions (Hickmann, 2017). Finally, in response to the findings of Giesekam et al. (2021), this paper highlights baseline data gaps in scope 3 disclosure and concludes with key policy recommendations for the future of carbon disclosure in the supply chain (Giesekam et al., 2021).

2. Methodology

2.1. Data preparation

First, this study considered 2018 greenhouse gas emissions data from self-reported, firm-level CDP disclosures in the food & beverage processing industry. Processing companies aggregate products from many smaller producers, such as farmers, who may lack the resources and expertise to report. A sample of larger firms were selected as the focus of this study because larger firms are for the most part better equipped financially and resource-wise to take on the task of accounting and reporting. A sample of 153 food & beverage processing firms were selected for analysis, after excluding companies that report primary activities of farming, logging, tobacco, and aquaculture, as well as one outlier. The processing companies in the sample report engaging in 15 distinct primary sub-activities, including alcoholic beverage and baked goods & cereals production. More than a quarter of companies in the sample (26%) are headquartered in the United States, and the remaining company headquarters are dispersed over three dozen countries around the world.

Companies that did not disclose emissions data to CDP in 2018 were not included in the scope of this study.[3]

All emissions reported to CDP were measured in units of metric tons of CO_2eq and organized into scopes. In this study, scope 1 data was used as reported, and scope 2 data were location-based, reflecting the average emissions intensity of the grid on which the energy consumption occurs (Meinrenken, 2020). Many companies also report a market-based scope 2 number, which represents the emissions a company is responsible for through its purchasing decisions. The authors chose to use location-based data to maximize the sample size. Under CDP's reporting structure, disclosure of scope 1 and 2 emissions is mandatory, while scope 3 disclosure is optional (Ascui and Lovell, 2011). Scope 3 emissions data were divided by category into seventeen subgroups, including the fifteen categories defined by the GHG Protocol, as well as Other Upstream and Other Downstream. In addition to emissions totals, the authors used CDP data that included firm national headquarter location; firm primary activity, sector, and industry; emissions methodology; and qualitative comments supplementing scope 1, 2, and 3 (for each category).

Revenue data for this study were collected from annual report top line statements for revenue, total sales, or turnover where publicly available online. Wherever possible, revenue was dated to 2018, the same year as the reported emissions data.[4] Revenue data were used for 121 of 153 food & beverage processing companies in the sample and reported in units of millions of USD; conversions were completed using financial data from Morningstar exchange rates in March 2020.

This study also aimed to address a gap in the literature around the influence of the Paris Agreement on corporate climate disclosure. Using CDP's country-level company headquarter data, the authors re-coded each company to be affiliated the headquarter country's UNFCCC negotiating allegiances, including the Umbrella Group (plus Turkey), EU/EIG, and G77 & China according to the Carbon Brief (Interactive: The UNFCCC Negotiating Alliances, 2015).[5] These groups were intended as a proxy for a shared set of policy priorities and development status within allied groups negotiating the international climate governance regime. Through this analysis, the authors aimed to provide an analysis of how participation in the Paris Agreement might affect a company's approach to transparency in carbon emissions.

Each headquarter country was also evaluated based on its 2018 Environmental Performance Index (EPI), to test the association between companies' emissions disclosure and home country regulatory framework (Wendling et al., 2018). The EPI, a metric of country-level sustainability published by the Yale Center for Environmental Law & Policy and the Columbia Earth Institute, uses 32 indicators to gauge progress against policy targets. The EPI is designed as a data-driven global scorecard and tool for governments to address environmental challenges, indicating its appropriateness as a variable to compare the strength of national regulation.

The EPI score provides a metric of country-level sustainability published by the Yale Center for Environmental Law & Policy and the Columbia Earth Institute.

2.2. Data interpretation

2.2.1. Descriptive statistics

This study identified Purchased Goods and Services as the most relevant and data-rich scope 3 category for the food & beverage processing sector, with 46% of companies disclosing. Using supplementary comments reported to CDP by companies that disclosed scope 3 emissions, the authors developed a qualitative index score for the Purchased Goods and Services category. The index measures the richness of the comments supplementing scope 3 disclosure based on five yes-or-no questions, awarding one point for each "Yes." A high score indicatives a more complete comment. The index results add to the findings of this study by highlighting specific aspects of scope 3 with potential for more reporting. These questions were designed to align with the accounting and reporting principles of the GHG Protocol Corporate Value Chain Standard, the 2018 CDP Scoring Methodology, and gaps in scope 3 reporting identified by Greene (2017):

1. Did the firm supplement their Purchased Goods emissions data with a comment? Y/N
2. Did the comment include a statement relating to relevance? Y/N
3. Did the comment include a statement relating to data source or calculation method? Y/N
4. Did the comment include a statement specifying or justifying inclusions/exclusions? Y/N
5. Did the comment include a goal or future intention to improve? Y/N

To contextualize the emissions data to company size, the authors also considered revenue data to provide a carbon intensity value based on the scale of a company's activities. Carbon intensity was defined as a ratio of combined scope 1 and scope 2 emissions over annual revenue, as a proxy

[3] The authors recognize these excluded firms may represent a substantial amount of global annual emissions generated by the food system.

[4] Some data uncertainty arose from this distributed sourcing method because data availability was limited for smaller firms, foreign firms, and privately-owned firms, and because firms use different start dates for fiscal years.

[5] For climate negotiations, groups of countries will gather in private to agree on shared positions, form an alliance, and negotiate together as a group. The European Union negotiates together as a group of 28 countries. Developing countries work together through the Group of 77. Following the Kyoto Protocol in 1997, the Umbrella Group also formed a coalition, comprised of Australia, Belarus, Canada, Iceland, Israel, Japan, New Zealand, Kazakhstan, Norway, the Russian Federation, Ukraine and the United States.

Table 1
Indirect food & beverage processing sector GHG emissions by scope 3 category. Purchased Goods is the category with the highest total self-reported emissions.

Scope 3 Category	MT of CO2eq
Purchased Goods	388,989,070
Use of Sold Products	64,477,478
Processing Sold Products	40,906,249
Downstream Transport	39,857,436
Upstream Transport	20,258,669
End of Life	10,583,387
Fuel & Energy	10,007,331
Waste	9,195,553
Capital Goods	8,876,627
Franchises	6,956,118
Investments	5,142,680
Employee Commuting	2,494,647
Downstream Leased Assets	2,491,494
Other Downstream	1,452,248
Business Travel	1,423,429
Other Upstream	302,565
Upstream Leased Assets	87,814

for firm size (Figure A.1).[6]

See the Appendix (Table A.1) for calculated variables and their relationship to raw data sourced from CDP, annual reports, and the EPI in tabulated form.

2.2.2. Predicting scope 3 disclosure

This paper includes linear regression, Chi-square tests, and multivariate regression models produced in Excel and Minitab. Linear regression and Chi-square tests were used to separately investigate the relationship of carbon intensity, EPI score, UNFCCC negotiating group, and primary activity on scope 3 disclosure. The Chi-square tests compared categorical variables, which the authors manually coded into levels in Excel from raw CDP data. Scope 3 categories reported were re-coded into levels: zero, 1 to 3, 4 to 8, and 9 to 13 categories reported. Country headquarter data were sorted into three levels, or negotiating groups: EU/EIG, Umbrella+, and G77 & China. Primary activity data were sorted into 6 levels, or activity groups. To make the analysis simpler and more meaningful, related food groups were self-categorized based on common characteristics of each of the sectors for production and retail. For instance, animal, dairy and egg are common food aggregations in the retail sector. There is no widely-recognized existing classification system at this granularity of primary activity, so the authors relied on domain knowledge.[7] The categories include: Alcoholic beverages; Animal, dairy & egg; Grain, baked goods, & cereal; Plant foods, confections, sugar, tea, & oils; Food & beverage wholesale & non-alcoholic beverages; and Other food processing. When comparing scope 3 disclosure to primary activity and UNFCCC negotiating group, the authors used weighted averages to highlight groups with above- and below-average performance.

2.2.3. Multivariate regression

The authors used two multivariate regression models to investigate what combination of variables best predicted companies' direct and energy-related absolute emissions and emissions performance. Independent variables of interest that the authors used included revenue (as a proxy for firm size), primary activity group, EPI Score (for country environmental sustainability), international climate negotiating group, and total scope 3 categories. The authors ran combinations of these variables in two series of multivariate regression models. Between negotiating group and EPI score, the latter country-level metric provides more information for the model as a continuous variable and offers a holistic, data-driven measure of a country's sustainability (Wendling et al., 2018). The dependent variable for the first regression model was total scope 1 and 2 emissions, to measure absolute emissions. For the second regression model, the dependent variable was scope 1 and 2 carbon intensity, to measure emissions performance. Total scope 3 categories were included to investigate whether companies with more comprehensive scope 3 disclosure would show better or worse absolute emissions or emissions performance. In the regression models, Minitab identified multiple outliers that the authors chose not to remove from the sample. Each of those individual observations were noted in the Results section. Tables and charts in this study were formatted in Minitab, Excel, and Word.

2.3. Limitations

Because the dataset used in this study was compiled from voluntary disclosures, data visualization may tell an incomplete story. Scope 3 emissions totals and any calculated variables including scope 3 emissions data are likely underreported, so companies that are leading the sector in sustainability practices may appear to be the worst emitters (Amran et al., 2016). Where data visualization may be potentially misleading, the authors provide accompanying text.

3. Results

3.1. Descriptive statistics: state of disclosure in the food & beverage processing sector

Of the companies in the food & beverage processing sector, 86.3% (133) reported scope 1 emissions, 76.0% (117) reported scope 2 location-based emissions, and 64.2% (99) reported at least one category of scope 3 emissions. When measured by scope 1 (direct), or scope 2 (energy-related) emissions, the ten food & beverage processing firms with the highest levels of reported emissions remained fairly consistent; 8 out of 10 companies showed up on both the scope 1 and scope 2 top ten lists. However, the list of top ten firms with the greatest overall emissions, including scope 3, introduced companies that did not feature on either the scope 1 or scope 2 top ten lists. A full list of top emitters by scope may be found in the Appendix (Table A.2).

Disclosure of scope 3 emissions was widely variable. Over a third (35.7%) of food & beverage processing companies did not disclose scope 3 emissions. The average (mean) company in the sector disclosed 3.48 of

Table 2
Cross-tabulation of self-reported scope 3 category disclosure by country headquarter negotiating group. Percentages show the difference between companies with a certain level of disclosure in a particular group as opposed to the average company with the same level of disclosure. Green highlights show above-average performance, red highlights show below-average performance.

	EU/EIG	Umbrella+	G77+China
zero	-11.96%	-11.96%	23.91%
1 to 3	9.42%	-3.08%	-6.34%
4 to 8	-1.48%	3.08%	-1.59%
9 to 13	4.02%	11.96%	-15.98%

[6] This approach was implemented after an initial comparison of the predictive strength of revenue for scopes 1 and 2 as compared to scopes 1, 2, and 3 with simple linear regression. The regression predicting scope 1 and 2 yielded an R-squared of 61.7% and a p-value of 0.00, while the regression including scope 3 yielded an R-squared of 43.5% with a p-value of 0.00. This confirmed Doda et al.'s (2016) assumption that companies report scope 1 and 2 more often, with more accuracy, and have more control over those emissions reductions. These regressions and illustrative figures are included in the Appendix (Fig. A1).

[7] Future studies could formalize these groupings with further analysis.

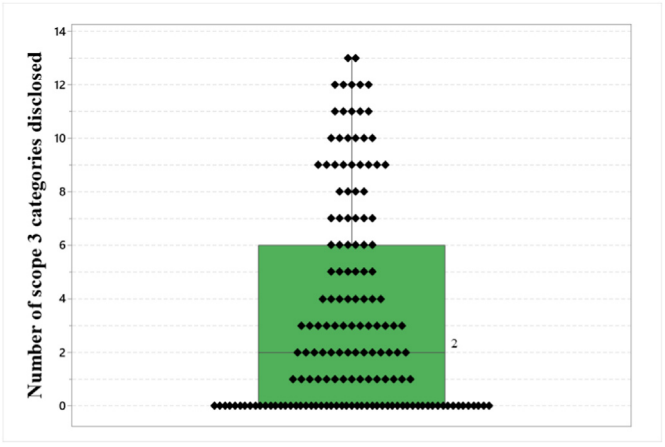

Fig. 1. A boxplot displaying firms in the food & beverage processing sector (N = 153) and the number of scope 3 categories they voluntarily disclosed (range 0–13).

15 scope 3 categories, which is below the average of 3.79 scope 3 categories disclosed to CDP in 2018 across firms in all industries. However, Scope 3 emissions represented 81.4% of the food & beverage processing sector's total disclosed emissions, which is less than the 83.7% average across all industries.[8] The median company disclosed only 2 of 15 scope 3 categories (Fig. 1). The authors noted that the share of total emissions from scope 3 should reflect the value chain emissions intensity of a particular industry, however, due to the voluntary nature of scope 3 reporting to CDP, this number better reflects completeness of disclosure.

Of the companies that did disclose scope 3 emissions, values ranged from 70 to 106,926,005 tons of CO_2eq. To account for firm size and activities, this range of disclosure can be considered in terms of percent of total disclosed emissions comprised of scope 3 (Fig. 2). A high percentage of overall emissions comprised of scope 3 is one potential measure of completeness of disclosure of scope 3 emissions, or supply chain transparency for emissions reporting.

A company may report a high number in one category of scope 3 and neglect to calculate and disclose emissions for the 14 other categories. Ideal scope 3 reporting should include calculations for all relevant upstream and downstream value chain activities, as well as explanations of any exclusions (GHG Protocol Agricultural Guidance, 2014). As the figure below indicates, less than 2% (3) of companies disclosed 13 scope 3 categories, and zero companies disclosed all 15 categories (Fig. 3).

The most commonly reported upstream category was Purchased Goods and Services (71), followed by Business Travel (63). The most commonly reported downstream category was Downstream Transport (58) and End-of-Life Treatment (34). A full list of scope 3 categories and the number of companies reporting may be found in the Appendix (Table A.3). The categories of scope 3 with the highest total reported emissions were Purchased Goods (388,989,070), Use of Sold Products (64,477,478), and Processing Sold Products (40,906,249) (Table 1).

[8] During the investigation, it was identified that one outlier firm in the sample, the Campbell Soup Company, disclosed the most complete scope 3 emissions data and accompanying qualitative comments, while also reporting disproportionately high scope 3 emissions totals. This outlying firm had revenue well below the mean of the sample size and its reported scope 3 emissions total was 45 times larger than that of the largest firm in the sample. This firm used the Quantis Scope 3 Evaluator Tool recommended by GHG Protocol and its data were published by CDP. The authors notified the firm, which then led its own investigation and notified the authors of a unit error in its scope 3 calculations. Its data were removed from the study sample, which shifted results for the entire food & beverage processing sector, and also demonstrated the challenges to finding appropriate estimates of scope 3 emissions. Another outlier, CDP Grupo, was also removed from the cross-industry average.

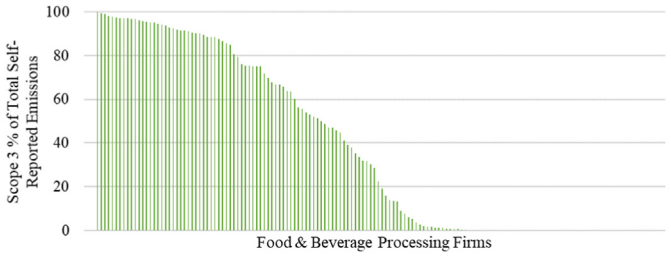

Fig. 2. Percentage of total self-reported emissions contributed by scope 3 categories for food & beverage processing sector companies (N = 153). A complete list of firms' percentages of total disclosed emissions contributed by scope 3 is available as supplementary material to this paper.

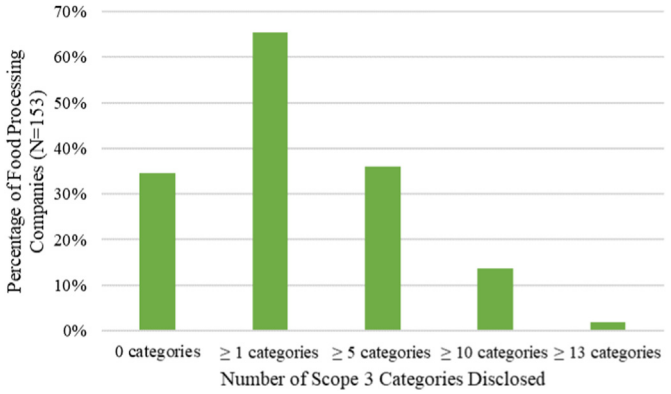

Fig. 3. Percentage of food & beverage processing companies (N = 153) self-reporting scope 3 emissions, by category. Less than 2% of companies disclose at least 13 categories, and zero companies disclose all 15 categories.

To compare emissions performance across firms, it is important to use a ratio of absolute emissions to a product or financial base. Firms with high carbon intensity values may be operating less "carbon-efficiently," producing more GHGs per dollar, than a firm with a lower carbon intensity. The top ten lists for scope 1, 2, and 3 emissions (Table 2) feature well-known multinational brands that make tens of billions of U.S. dollars in annual revenue. Ranked by carbon intensity, defined as the ratio between absolute emissions and revenue, the list of firms with top ten emissions changes considerably and the largest absolute emitters disappear from the list. The list of top ten best emissions performers includes companies that range in size, from firms that generate less than $20 million in annual revenue, to firms that generate over $20,000 million. For a list of best and worst performers, see the Appendix (Table A.4). The authors also noted top emissions performers included companies with a wide range of primary activities.

3.2. *Disclosure best practices*

Purchased Goods was the scope 3 category that most companies in the food & beverage processing sector chose to disclose; it was also the category with the highest total reported emissions. The index score below measures the completeness of supplementary comments for Purchased Goods emissions. A high score indicates a more complete comment. The distribution of scores is displayed as a histogram below; most companies that supplemented their emissions data with a comment included two of the five index score criteria (Fig. 4).

Out of the sample data, only two firms scored all five possible points, and only three firms scored four points. When it came to disclosing relevant scope 3 information, these companies were top performers. In general, companies were most likely to comment on data source or method, and second-most likely to specify inclusions and exclusions. Only four companies commented on future goals.

Table 3
Cross-tabulation of self-reported scope 3 category disclosure by primary activity group. Percentages show the difference between companies with a certain level of disclosure in a particular group as opposed to the average company with the same level of disclosure. Green highlights show performance above average, red highlights show performance below average.

	Alcoholic beverages	Animal, dairy, & egg	Grain, baked goods, & cereal	Plant foods, confections, sugar, tea, & oils	Food & beverage wholesale & non-alcoholic beverages	Other food processing
zero	-12.47%	-12.47%	9.18%	18.72%	0.76%	-3.72%
1 to 3	-4.01%	10.28%	13.09%	-7.82%	-9.30%	-2.24%
4 to 8	-5.57%	8.71%	-10.77%	5.14%	6.07%	-3.58%
9 to 13	22.05%	-6.52%	-11.50%	-16.04%	2.47%	9.54%

Table 4
A series of multivariate regression models predicting self-reported direct and energy-related emissions. The models measure the partial effect of revenue, scope 3 category disclosure, EPI score, international climate negotiating group, and primary activity group. Revenue and the activity group of "Plant foods, confections, sugar, tea, & oils" were significant predictors.

Scope 1 and 2 total emissions disclosure				
Variable	A	B	C	D
Revenue	107.21*** (7.41)	107.10*** (7.61)	107.45*** (7.73)	108.02*** (7.65)
Scope 3 Categories	−52,583 (37,510)	−27,516 (39,181)	−14,729 (40,422)	−16,354 (40,368)
EPI Score				−15,548 (13,842)
UNFCCC Negotiating Group				
G77+China			722,877 (474,964)	
Umbrella + Turkey			188,863 (367,437)	
Primary Activity Group (AG)				
Animal, dairy, & egg (AG)		401,281 (576,471)	364,921 (576,894)	405,393 (575,674)
Food & beverage wholesale; non-alcoholic beverages (AG)		52,950 (527,806)	89,346 (529,874)	51,370 (527,067)
Plant foods, confections, sugar, tea, & oils (AG)		1,461,345** (662,173)	1,418,658** (662,259)	1,432,966** (661,726)
Grain, baked goods, & cereals (AG)		676,948 (658,870)	729,912 (663,116)	676,541 (657,946)
Other food processing (AG)		168,023 (478,622)	110,973 (492,246)	116,147 (480,176)
Constant	216,473 (243,522)	−216,019 (483,326)	−492,304 (524,312)	830,860 (1,049,596)
R-squared	68.13%***	70.36%***	71.11%***	70.76%***
R-squared (adjusted)	67.48%	68.13%	68.26%	68.22%
Number of observations included	109			

Standard errors in parentheses.
*, **, *** indicates significance at the 90%, 95%, and 99% level, respectively.

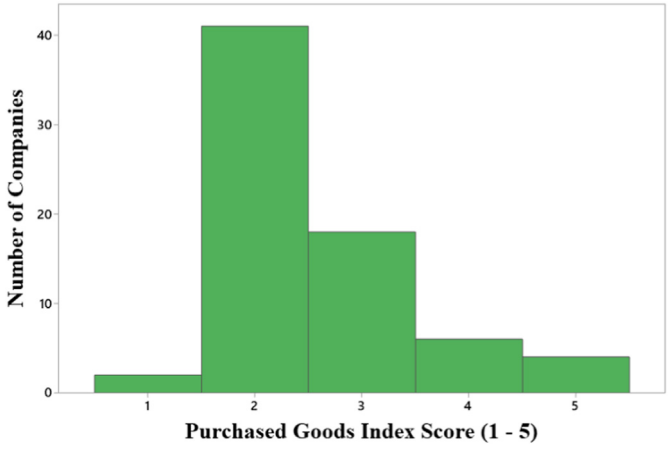

Fig. 4. The distribution of scores (1–5) rating the quality of self-reported supplementary comments for the scope 3 category of Purchased Goods.

3.3. Predictive factors of scope 3 disclosure by category

The authors ran a series of four tests to investigate what variables (scope 1 and 2 emissions totals, primary activity, climate negotiating group of headquarter country, and EPI score of firm headquarter country) might be significantly associated with scope 3 disclosure.

The first null hypothesis was that a company's direct and energy-related emissions performance, measured by carbon intensity, is independent of a company's scope 3 disclosure by category. The resulting trendline was slightly negative, but failed to reject the null hypothesis, meaning a firm's emissions performance for disclosed scope 1 and 2 emissions had no significant predictive power over the number of scope 3 categories disclosed (Fig. 5).

The second null hypothesis was that the Environmental Performance Index (EPI) score of a company's headquarter country is independent of a company's scope 3 disclosure by category. The resulting trendline was positive and rejected the null hypothesis with an R-squared of 13.0% and a p-value of 0.00, suggesting the EPI score of a company's headquarter country may be related to the company's scope 3 disclosure by category (Fig. 6).

The third null hypothesis was that the international climate (UNFCCC) negotiating group of a firm's headquarter country is independent of its scope 3 disclosure by category. The chi-square test yielded a p-value of 0.00017, well below the accepted $\alpha < 0.05$ cutoff for significance. This suggested the UN climate change negotiating group of a company's headquarter country is in fact related to its scope 3 disclosure. Comparing the average disclosure of each negotiating group to the average for all companies, companies in Umbrella Group countries had the best disclosure, followed by those in EU/EIG countries (Table 2).

The fourth, and final, null hypothesis was that the primary activity of a firm is independent of its scope 3 disclosure by category. The chi-square test yielded a p-value of 0.0537, just above the $\alpha < 0.05$ cutoff for

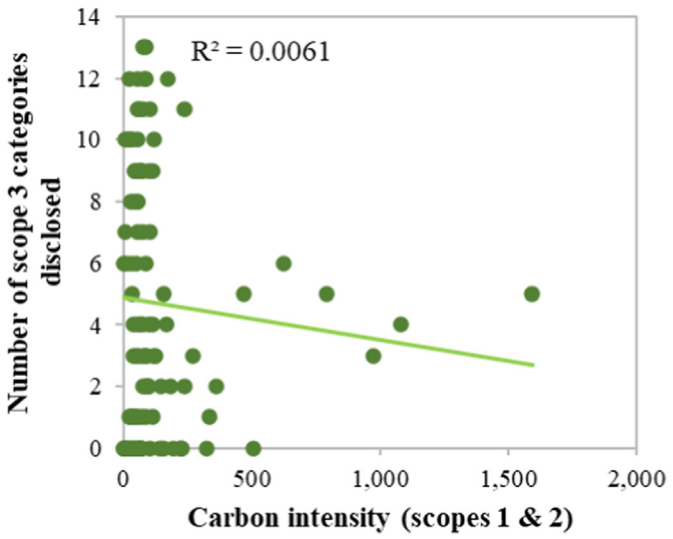

Fig. 5. Linear regression displaying the relationship between a company's self-reported emissions performance, or carbon intensity, and its self-reported scope 3 disclosure by category.

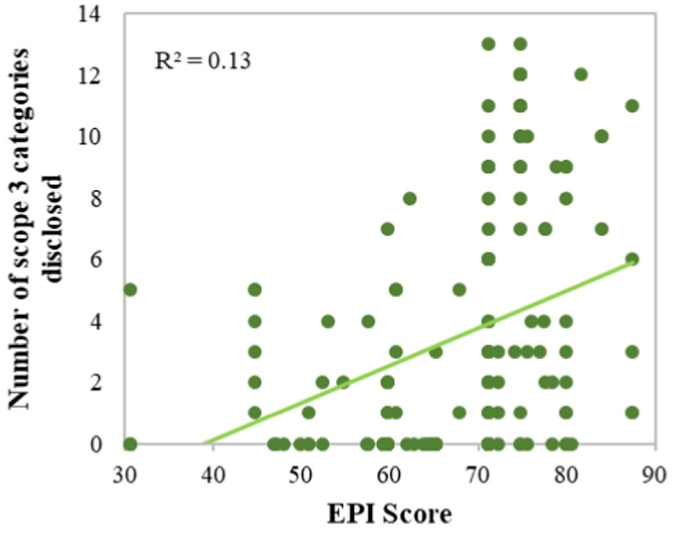

Fig. 6. Linear regression displaying the relationship between EPI score of a company's headquarter country and the company's self-reported scope 3 disclosure by category.

significance. While the test failed to reject the null hypothesis, a comparison of averages between activity groups offered further results. Comparing the average disclosure of each primary activity group to the total average for all companies, alcoholic beverage companies had the best disclosure, followed by other food processing. "Grain, baked goods, & cereals" and "Plant foods, confections, sugar, tea, & oils" disclosed the fewest categories on average (Table 3).

In summary, two of the four hypothesis tests yielded p-values less than $\alpha < 0.05$, leading the authors to reject the null hypothesis. Both of these categories, negotiating group and EPI score, related to a company's headquarter country, suggesting there is a significant relationship between headquarter country—specifically its international climate negotiating group and environmental performance—with completeness of value chain emissions reporting. According to the regression results, emissions performance, measured by carbon intensity, was not a significant predictor of scope 3 reporting. Primary activity group just failed to meet the $\alpha < 0.05$ cutoff to reject the null hypothesis, but differences in activity group averages revealed that companies in certain groups, like alcoholic beverages and other food processing, reported higher numbers of scope 3 categories than others.

3.4. Predictive factors of firms' direct and energy-related emissions performance

Using the outcome variable of scope 1 and 2 total emissions, the authors designed a multivariate regression model to explore whether firm size (measured by annual revenue), primary activity, scope 3 disclosure by category, international climate negotiating group, or EPI scores are significant predictors of a company's direct and energy-related emissions. Alternate models using different combinations of variables were tested and ultimately not selected. Although the inclusion of negotiating group yielded a slightly higher R-squared value (71.11%), the authors noted EPI score provided more information for the model as a continuous variable and is a more holistic, data-driven measure of a country's sustainability. In the below table, the right-hand model yielded an R-squared value of 70.76% and standard deviation of 1,493,075 (Table 4). The two significant predictors in the model were revenue and the primary activity group term for "Plant foods, confections, sugar, tea, & oils" with associated p-values of $\alpha < 0.05$ and positive coefficients. This suggested increasing firm size is a significant predictor of increasing scope 1 and 2 emissions totals, and that firms in the "Plant foods, confections, sugar, tea, & oils" activity group are likely to have higher scope 1 and 2 emissions totals (Table 4). Although the "Plant foods, confections, sugar, tea, & oils" had a low p-value, primary activity as a category was not significant overall. According to this model, scope 3 disclosure by category and EPI score are also not significant predictors of scope 1 and 2 emissions.

Certain companies were identified by the model as unusual observations with outsized residuals. Firms with large positive residuals have relatively high emissions, while firms with small residuals have relatively low emissions. Revenue was the only significant predictor overall in this model. This may obscure the partial effect of other independent variables.

To investigate the partial effect of independent variables other than revenue, the authors ran a second series of multivariate regressions predicting emissions performance by using carbon intensity as the dependent variable. This model noted no significant impact of scope 3 disclosure on scope 1 and 2 emissions performance. Overall, primary activity group was not a significant predictor; only one regression showed the "Food & beverage wholesale and non-alcoholic beverages" group to be a significant predictor, and only at the 90% level. Both UNFCCC negotiating group and EPI score were significant predictors of emissions performance at the 99% level; the coefficient was positive and significant for G77 & China countries, while the coefficient for EPI score was negative and significant (Table 5). The R-squared values for this series of models ranged from 10 to 22%.

The first multivariate regression model, which uses scope 1 and 2 emissions totals as the dependent variable, showed that revenue—or firm size—was a significant predictor of absolute emissions. To test whether larger companies have better emissions performance, the authors created a scatterplot with a line of best fit for ln (revenue) (x) and carbon intensity (y). As seen in Fig. 7, the predictive power of the line of best fit was less than 1%, and the slope nearly flat. This suggested large firms are not more efficient in terms of direct and energy-related emissions.

4. Discussion

The results of this work revealed the current level of voluntary emissions disclosure in the food & beverage processing sector and found scope 3 disclosure lacks completeness and consistency. This finding was consistent with Li et al. (2020)'s cross-industry analysis and Giesekam et al. (2021)'s investigation of Science-Based Targets (Jaggi et al., 2011; Qian and Schaltegger, 2017), and underlined Patchell (2018)'s (Patchell, 2018) concern about scope 3's failure to compel firms to report a full

Table 5
Effect of scope 3 category disclosure, headquarter country EPI Score, UNFCCC Negotiating Group, and Primary Activity group on emissions performance, as measured by carbon intensity of direct and energy-related emissions. EPI Score and UNFCCC Negotiating Group (G77 & China) were both significant predictors.

Carbon intensity (Scope 1 & 2 total emissions over revenue)				
Variable	A	B	C	D
Scope 3 Categories	−0.42 (5.63)	1.45 (5.42)	2.41 (6.00)	4.48 (5.73)
EPI Score	−6.66*** (2.01)		−6.73*** (2.06)	
UNFCCC Negotiating Group				
G77+China		249.8*** (66.0)		256.6*** (67.7)
Umbrella + Turkey		−28.8 (49.2)		−34.2 (51.7)
Activity Group (AG)				
Animal, dairy, & egg (AG)			57.6 (85.5)	54.1 (81.8)
Food & beverage wholesale; non-alcoholic beverages (AG)			91.7 (78.3)	123.9* (75.2)
Plant foods, confections, sugar, tea, & oils (AG)			135.7 (98.8)	122.1 (94.2)
Grain, baked goods, & cereals (AG)			102.3 (98.1)	146.1 (94.0)
Other food processing (AG)			47.2 (71.7)	82.0 (69.8)
Constant	611*** (138)	108.1 (47.1)	57.6 (85.5)	10.6 (74.4)
R-squared	10.89%***	18.89%***	13.33%*	22.23%***
R-squared (adjusted)	9.07%	16.39%	6.8%	15.47%
Number of observations included	109			

Standard errors in parentheses.
*, **, *** indicates significance at the 90%, 95%, and 99% level, respectively.

audit of their scope 3 emissions. The low number of average reported categories and the wide range of scope 3 intensities confirmed scope 3 disclosure by food & beverage processing companies lags behind disclosure for scopes 1 and 2 (Figs. 1 and 2). Judging from the emissions intensity of agricultural production, the food & beverage processing sector should have a higher-than-average, not lower-than-average, scope 3 percentage total, suggesting underreporting remains an issue for scope 3 (Garnett, 2011). For the food & beverage processing sector, the most commonly reported scope 3 categories were Purchased Goods & Services, Business Travel, and Upstream & Downstream Transport (Table 1). Purchased Goods is the category with the highest level of reported emissions, while Business Travel is category with the second lowest. This suggests that companies are choosing to calculate and report scope 3 categories at their discretion (Jaggi et al., 2011; Greene, 2017). Some reporting choices may be based on relevance, like Purchased Goods, while others, like Business Travel, may be based on ease of estimation or perceived importance to consumers, in line with signaling or legitimacy theory.

Analysis of qualitative and quantitative data from CDP shed light on best disclosure practices in the food & beverage processing sector, investigating not only the quantity but the quality of scope 3 disclosure in response to Li et al. (2018)'s and Mahapatra et al. (2021)'s call for further research (Li et al., 2018; Younis and Sundarakani, 2019a). The Purchased Goods index score revealed very few top performers; only two firms in the sample scored 5 out of 5 points, and only three additional firms scored 4 out of 5 (Fig. 4). Companies were most likely to provide qualitative comments on data source or method, rather than in/exclusions. Companies were least likely to comment with future scope 3 goals, consistent with Giesekam et al. (2021) (Qian and Schaltegger, 2017).

The authors identified that the self-reported data from one outlier firm contained a unit error in its scope 3 calculations and its data were removed from the study sample. The removal of the outlier shifted results for the entire food & beverage processing sector, and also demonstrated the challenges to finding appropriate estimates of scope 3 emissions.

The second research aim of this paper was to investigate how emissions performance, national environmental policy, international climate negotiation group, and primary activity influence scope 3 disclosure. Results revealed both EPI score and negotiating group of a company's headquarter country had a significant relationship to the completeness of a company's scope 3 disclosure (Fig. 6; Table 2). In line with institutional theory, a higher EPI score predicted a higher number of scope 3 categories disclosed (Hahn et al., 2015; Amran et al., 2016; Li et al., 2018). In terms of negotiating group, companies headquartered in countries belonging to the Umbrella Group (plus Turkey) had the best scope 3 disclosure, followed by companies headquartered in the EU/EIG, followed by those in G77 & China. The authors noted Umbrella Group and G77 & China both include a large and diverse group of countries with a range of individual negotiating positions not captured by this metric. G77 & China is also a group of self-identified developing countries, so the group's negative correlation with scope 3 disclosure may suggest a need for increased international financial and technical support for food system decarbonization at the country level, particularly for developing countries. In line with Hickmann (2017) and institutional theory, stronger political cooperation at the international level, including increased support for decarbonized development pathways, may create pressure on companies around the world to improve scope 3 disclosure (Hickmann, 2017).

National governments have an important role in reducing global supply chain emissions, even when not directly mandating emissions

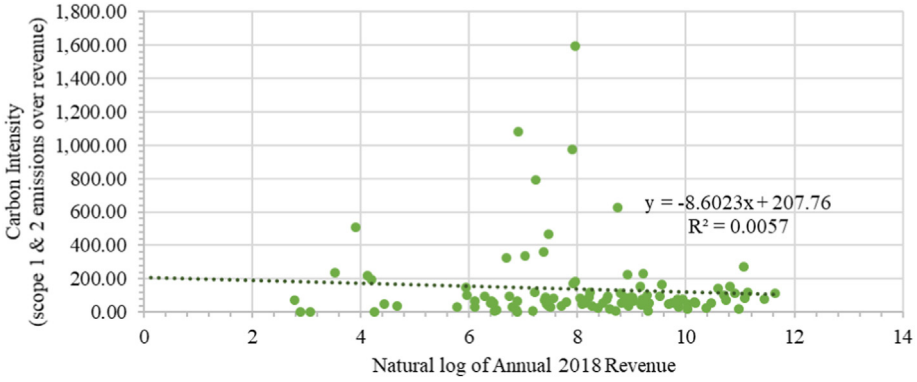

Fig. 7. Scatterplot of ln (revenue) against carbon intensity, with a line of best fit. The shallow slope and low R-squared suggest the size of a firm is not correlated with self-reported emissions performance.

transparency. This paper's contribution is specific to firm-level emissions and supply chain disclosure, with implications for corporate management and governments, while other studies, for example Kucukvar et al. (2019), take a country-level approach to food supply chain impacts (Kucukvar et al., 2019). Currently, no governing body requires scope 3 reporting, but many countries and central banks are signaling their intention to integrate climate concerns: Shell was recently mandated by a Dutch court to increase its climate ambition across all scopes (Younis and Sundarakani, 2019b; Joselow, 2021). So, although voluntary corporate action is not a replacement for climate policy, it is important to develop firm-level scope 3 calculating and reporting capacity in preparation for mandatory reporting. In addition, corporate supply chain emissions disclosure is critical to meeting Science-Based Targets in the short-term and getting on track to meet the Paris aligned goal of net-zero emissions by 2050.[9]

The relationship between scope 3 disclosure and a company's primary activity was not significant. However, alcoholic beverage companies in this sample had the best average disclosure, followed by "Other food processing," "Grain, baked goods, & cereals," and "Plant foods, confections, sugar, tea, & oils" activity groups disclosed the fewest categories on average (Table 3).

Investigating this paper's third research aim, the authors found annual revenue was a significant predictor of a company's absolute scope 1 and 2 total emissions. The first series of multivariate regressions explained over 70% of variance, underlining the predictive power of firm size on direct and energy-related emissions (Table 4). A few firms stood out with unusually positive and negative residuals—meaning their emissions were relatively high and low, respectively. This demonstrated the agency, regardless of company size, to reduce emissions and lead the sector through intra-organizational practices (Damert and Baumgartner, 2018).

Scope 3 disclosure by category, primary activity, and country headquarter-based variables were not significant predictors of a company's scope 1 and 2 emissions. However, when the authors replaced absolute emissions with carbon intensity as the dependent variable, the second series of multivariate regressions revealed EPI score and the G77 & China negotiating group as significant predictors (Table 5). The negative correlation of EPI score and carbon intensity suggested the relevance and impact of country-level regulation on improved corporate emissions performance, complimenting the findings of O'Rourke (2014) and Amran et al. (2016) in line with institutional theory (O'Rourke, 2014; Amran et al., 2016). The authors noted Damert and Baumgartner (2018) (Damert and Baumgartner, 2018) did not find a relationship between the company's home country climate policy regime and climate response strategies. This paper's preliminary findings suggest national regulation could act as leverage for more disclosure.

Firms located in headquarter countries belonging to the G77 & China climate negotiating group had significantly higher carbon intensities, or poorer emissions performance. Members of the G77 comprise a large group of nations with diverse policies and negotiating stances, however, their shared status as developing countries acts as a strong force for diplomatic alignment. The relatively poor emissions performance of firms in G77 countries may reflect this shared development status. To more closely measure the effect of the international climate governance regime on supply chain disclosure and emissions, the authors identified a need for further research through the use of appropriate metrics relevant to the Paris Agreement framework, such as ambition of Nationally Determined Contributions.

Finally, when the authors plotted carbon intensity against revenue, the resulting line of best fit was nearly flat, with an R-squared value of less than 1% (Fig. 7). These results implied that larger companies were not necessarily more emissions efficient, a finding not widely reported in extant literature. Younis and Sundarakani (2019a, 2019b) (Younis and Sundarakani, 2019b) found a positive relationship between firm size and general environmental performance, but the scope of their study included only firms within the UAE. This paper's findings may inform future research and policies that concern changes to the organization and structure of the global food system to lessen climate impact.

5. Conclusion

Conducting business as usual is not a viable 21st century pathway for the food & beverage processing sector. A deep shift aligned with a net-zero future is required in how food is grown, processed, and delivered to consumers. You can't reduce what you don't measure, and CDP disclosures represent the most comprehensive set of carbon emissions measurements available today.

This study conducted a novel study of the state of emissions disclosure within the food & beverage sector, suggesting that significant progress remains to be made toward full climate impact transparency. While scope 1 and 2 disclosure were more commonly disclosed to CDP, scope 3 emissions—representing over 80% of emissions in the food industry—remained incomplete and inconsistent. Improved scope 3 accounting and disclosure can help companies identify leverage points for decarbonization across their value chains, to set ambitious and realistic mitigation goals built on robust data that accelerates up- and downstream transition to a zero-carbon food sector (Ortas et al., 2015; Lohmann, 2009; Jaggi et al., 2011). Thus, the authors offer the following recommendations and calls for future work:

- There is a need for harmonized emissions accounting methodologies that allow companies to share emissions consistently across the supply chain. Different supply chain players have varying approaches and capabilities for accounting and reporting, which is leading to challenges for understanding the full supply chain impact. Harmonized carbon accounting allows for apples-to-apples comparison of corporate and carbon footprints, enabling data-driving decision making around carbon emissions. The authors recommend the adoption of a framework that encourages transparency of the data sources used to calculate emissions, rewarding companies that use real supplier data above estimation tools, as well as third party verification of disclosed emissions.
  - o Initiatives such as the Coalition on Materials Emissions Transparency (COMET), Global Logistics Emissions Council, and World Business Council for Sustainable Developments' Pathfinder program all represent meaningful business-driven programs to advance carbon accounting.
- Furthermore, there is a need to connect corporate and country-level carbon accounting. Both parties have access to different types of data, but often the calculations are disconnected and the data unshared. Platforms like CDP offer a place for the transparent sharing of data, though new systems and methods are needed to enable the transfer of meaningful data. Once complete, the COMET Framework (United Nations Climate Change, 2021) will seek to address this fragmentation and provide insights for state and non-state actors.
  - o As this study showed, a headquarter country's international climate negotiating group influences the level of disclosure by companies. This influence could be further leveraged by collaborating on carbon emission accounting methods and practices.
- For smaller businesses, or companies just beginning their sustainability journey, there is a need for additional technology and educational resources on carbon emissions accounting. There is a clear challenge for smaller businesses' capability to collect and report on their own emissions. While CDP offers many helpful trainings, and numerous consultants offer carbon accounting services, larger companies can support these initiatives by working with their smaller suppliers to support the development of internal carbon tracking

[9] Science Based Targets initiative plans to offer sector-specific guidance for the Agriculture, Forestry and Other Land Use by Q4 2021: https://sciencebasedtargets.org/sectors/forest-land-and-agriculture.

frameworks. The authors recommend providing increased resources and guidance for sector-specific scope 3 disclosure, target-setting, and implementation.

- As companies shift from a dependence on industry average data to supplier data, reliable systems for emissions allocation are needed. While this study focused on the allocation of emissions to revenue, emissions allocations to customers, kilograms of product sold, or activity metrics like ton-kilometers are also highly relevant to manage supply chains sustainably.
- Further research might be done into the differences in supply chain structure between companies with specific primary activities that facilitate better, or worse, scope 3 calculation and reporting. To connect the dots between scope 3 disclosure and decarbonization, the authors also suggest further research into firms' motivation and performance, to contribute to the existing literature on legitimacy and stakeholder theories.
- The authors invite further research and guidance on the qualitative side of scope 3 reporting, including the development of a more sophisticated index that scores for factors like quality of data source (i.e. primary supplier data, third-party verification), extensiveness of inclusions, and ambition of goals.

Food supply chains link producers, processors, and consumers in a collective process (Fresco, 2009). Scope 3 is a quantitative embodiment of this process, revealing the responsibility food companies share in the production of agricultural GHG emissions upstream in their supply chains. While scope 3 reporting in the food & beverage processing sector may never be as complete or accurate as scope 1 and 2, improved calculation and disclosure is one of a suite of important actions a company can take to design and implement effective carbon mitigation strategies. While disclosure alone won't lead to decarbonization, full and accurate disclosure may seriously improve the relationship between actors in a value chain, allow companies to increase the ambition of their emissions reduction targets, and improve supply chain traceability.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Table A.1
All calculated variables and their relationship to raw data sourced from CDP, annual reports, and the EPI.

Variable	Description	Relationship to Raw Data
Scope 1 & 2 Totals	The combined GHG emissions of a company's direct and indirect energy emissions for the reporting year	The sum of scope 1 and scope 2 Location Based data from CDP
Scope 3 Totals	The combined GHG emissions of all supply chain activities up/downstream for the reporting year	The sum of all seventeen scope 3 category emissions from CDP
Scope 1, 2, & 3 Totals	The combined GHG emissions of all direct and indirect sources for the reporting year	The sum of scope 1, scope 2 location based, and scope 3 totals from CDP
Scope 3% of total	The percentage that scope 3 comprises of the total GHG emissions a company disclosed in the reporting year	Scope 3 Totals/SUM of scope 1,2,3 Totals
Total scope 3 categories	The total number of scope 3 categories a company disclosed in the reporting year	The sum of disclosure indicator variables (1,0) for all 17 scope 3 columns
Purchased Goods & Services score	An index score from 0 to 5 based on five Y/N questions measuring the quality of a company's qualitative Purchased Goods & Services comments	Index score for scope 3 Purchased goods comments. Purchased goods is the most relevant upstream category of scope 3 emissions, based on total reported emissions and number of reporting firms in the sector
Carbon intensity (scope 1 & 2)	GHG emissions per unit; with regards to this study, a company's annual GHG emissions for the reporting year over their revenue in millions of USD for the reporting year	Scope 1 & 2 Totals from CDP divided by Revenue ($ million) 2018 from individual company reports
Negotiating Group	Climate policy alignment in UNFCCC negotiations, broken into three groups: Umbrella+, EU/EIG, and G77 & China	Assigned to each company based on their country headquarter data from CDP
EPI Score	Emissions performance of the country headquarters of a company, from 0 to 100. Scores are from the 2018 EPI, a global metrics tool published by the Yale Center for Environmental Law & Policy and the Columbia University Earth Institute	Assigned to each company based on their country headquarter data from CDP
Activity Group	The kind of primary business activity a company engages in, broken into six groups: alcoholic beverages; animal, dairy & egg; grain, baked goods, & cereal; plant foods, confections, sugar, tea, & oils; food & beverage wholesale & non-alcoholic beverages; and other food processing	An umbrella category created from individual primary activities reported by individual firms to CDP. Related food groups were self-categorized based on common characteristics of each of the sectors for production and retail. For instance, animal, dairy and egg are common food aggregations in the retail sector. There is no widely-recognized existing classification system at this granularity of primary activity, so the authors relied on domain knowledge.

Table A.2
Top 10 scope 1 (direct) emitters, top 10 scope 2 (energy-related) emitters, and top 10 combined scope 1, 2, & 3 emitters in food & beverage processing sector (as self-reported to CDP in 2018).

Organizations Ranked by Scope 1 Emissions	Organizations Ranked by Scope 2 Emissions	Organizations Ranked by Combined Scope 1, 2, &">& 3 Emissions
1. Archer Daniels Midland	1. Cargill	1. Nestlé
2. Cargill	2. Nestlé	2. PepsiCo, Inc.

(*continued on next column*)

Table A.2 (*continued*)

Organizations Ranked by Scope 1 Emissions	Organizations Ranked by Scope 2 Emissions	Organizations Ranked by Combined Scope 1, 2, &">& 3 Emissions
3. JBS S/A	3. Archer Daniels Midland	3. The Coca-Cola Company
4. Mitsubishi Corporation	4. Tyson Foods, Inc.	4. Archer Daniels Midland
5. Wilmar International Limited*	5. Mitsubishi Corporation	5. Anheuser Busch InBev
6. PepsiCo, Inc.	6. Anheuser Busch InBev	6. Mitsubishi Corporation
7. NewAge Indústria de Bebidas	7. JBS S/A	7. Mars
8. Anheuser Busch InBev	8. PepsiCo, Inc.	8. The Kraft Heinz Company
9. Nestlé	9. Bunge	9. Fonterra Co-operative Group
10. Tyson Foods, Inc.	10. Mars	10. Danone

Table A.3
Most commonly disclosed scope 3 categories in the food & beverage processing sector (downstream and upstream).

Upstream Scope 3 Category	#">"># of Companies Reporting	Downstream Scope 3 Category	#">"># of Companies Reporting
Purchased Goods	71	Downstream Transport	58
Business Travel	63	End-of-life Treatment	34
Upstream Transport	57	Use of Sold Products	28
Fuel- and Energy-Related Activities	56	Processing of Sold Products	11
Waste Generated in Operations	56	Downstream Leased Assets	10
Employee Commuting	42	Investments	8
Capital Goods	28	Franchises	5
Upstream Leased Assets	10	Other downstream	3
Other upstream	1		

Table A.4
Top ten firms with highest carbon intensities, a measure of poor emissions performance, alongside top ten firms with lowest carbon intensities, a measure of strong emissions performance. All carbon intensities were calculated using combined self-reported scope 1 & 2 emissions over annual revenue.

Top 10 Poor Performers	Top 10 Strong Performers
1. NewAge Indústria de Bebidas	1. Griffith Foods
2. Tongaat Hulett Ltd	2. Crown Prince
3. Tate & Lyle	3. REMA1000
4. RCL Foods Ltd	4. Keurig Green Mountain*
5. Ingredion Incorporated	5. Remy Cointreau
6. Waychein	6. Sensory Effects**
7. Remgro	7. Royal Wessanen NV
8. Tiger Brands	8. Marico
9. Pioneer Foods	9. Suntory Beverage & Food
10. Suiker Unie	10. McCormick & Company, Inc.

*(merged with Dr Pepper Snapple Group '18).
**(acquired by Ralcham '13)

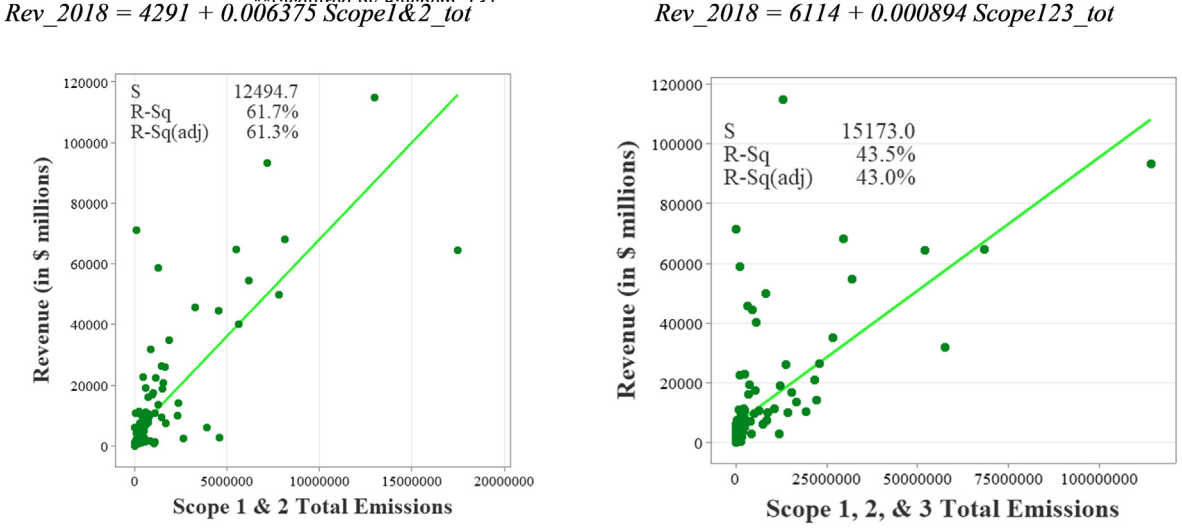

Fig. A.1. A pair of linear regressions tested the relative predictive strength of self-reported scope 1 and 2 total emissions and scope 1, 2, and 3 total emissions on revenue, as a proxy for firm size. Self-reported scope 1 and 2 total emissions (R-sq 61.7%) was a stronger predictor than scope 1, 2, and 3 total emissions (R-sq 43.5%). Both regressions are significant at a threshold of 99%.
Rev_2018 = 4291 + 0.006375 Scope1&2_tot Rev_2018 = 6114 + 0.000894 Scope123_tot .

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clpl.2021.100002.

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References

Al-Tuwaijri, Sulaiman, Christensen, Theodore E., Hughes, K.E., 2003. The Relations Among Environmental Disclosure, Environmental Performance, and Economic Performance: A Simultaneous Equations Approach. " SSRN Scholarly Paper ID 405643. Social Science Research Network, Rochester, NY. https://doi.org/10.2139/ssrn.405643.

Amran, Azlan, Ooi, Say Keat, Cheng, Yew Wong, Hashim, Fathyah, 2016. Business strategy for climate change: an ASEAN perspective: business strategy for climate change. Corp. Soc. Responsib. Environ. Manag. 23 (4), 213–227. https://doi.org/10.1002/csr.1371.

Ascui, Francisco, Lovell, Heather, 2011. "As frames collide: making sense of carbon accounting - ProQuest." *accounting*. Audit. Acc. J. Brad. 24 (8), 978–999. https://doi.org/10.1108/09513571111184724.

Bager, Simon, Campbell, Bruce, Holt, Lucy, Vermeulen, Sonja, 2019. "The Big Facts: Food Emissions Supply Chain Emissions." CGIAR Research Program on Climate Change, Agriculture and Food Security. https://ccafs.cgiar.org/bigfacts/#theme=food-emissions.

Barrow, Martin, Buckley, Benedict, Caldicott, Tom, Tom, Cumberlege, Hsu, John, Scott, Kaufman, Ramm, Kevin, et al., 2013. "Technical Guidance for Calculating Scope 3 Emissions." Corporate Value Chain Accounting & Reporting Standard. WRI & WBCSD.

Bhatia, Pankaj, Ranganathan, Janet, 2004. The Greenhouse Gas Protocol. World Resources Institute (WRI). March 1, 2004. https://www.wri.org/publication/greenhouse-gas-protocol.

Bhatia, Pankaj, Cummis, Cynthia, Brown, Andrea, Rich, David, Draucker, Laura, Lahd, Holly, 2011. Corporate value chain (scope 3) standard. Greenh. Gas Protocol, 2011. https://ghgprotocol.org/standards/scope-3-standard.

Blanco, Christian, Caro, Felipe, Corbett, Charles J., 2016. The state of supply chain carbon footprinting: analysis of CDP disclosures by US firms. J. Clean. Prod. 135 (November), 1189–1197. https://doi.org/10.1016/j.jclepro.2016.06.132.

Business Leaders Taking Action, 2021. United nations global compact. June 3, 2021. https://www.unglobalcompact.org/take-action/events/climate-action-summit-2019/business-ambition/business-leaders-taking-action.

Cho, Charles H., Patten, Dennis M., 2007. "The role of environmental disclosures as tools of legitimacy: a research note." *accounting*. Org. Soc. 32 (7–8), 639–647.

Clarkson, Peter M., Overell, Michael B., Chapple, Larelle, 2011. Environmental reporting and its relation to corporate environmental performance. Abacus 47 (1), 27–60. https://doi.org/10.1111/j.1467-6281.2011.00330.x.

Climate action 100+ issues its first-ever net zero company benchmark of the world's largest corporate emitters. Climate Action 100+, 2021. March 22, 2021. https://www.climateaction100.org/news/climate-action-100-issues-its-first-ever-net-zero-company-benchmark-of-the-worlds-largest-corporate-emitters/.

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F.N., Leip, A., 2021. Food systems are responsible for a third of global anthropogenic GHG emissions. Nat. Food 2 (3), 198–209. https://doi.org/10.1038/s43016-021-00225-9.

Dahlmann, Frederik, Roehrich, Jens K., 2019. Sustainable supply chain management and partner engagement to manage climate change information. Bus. Strat. Environ. 28 (8), 1632–1647. https://doi.org/10.1002/bse.2392.

Damert, Matthias, Baumgartner, Rupert J., 2018. "External pressures or internal governance – what determines the extent of corporate responses to climate change? Corp. Soc. Responsib. Environ. Manag. 25 (4), 473–488. https://doi.org/10.1002/csr.1473.

Doda, Baran, Gennaioli, Caterina, Gouldson, Andy, Grover, David, Sullivan, Rory, 2016. Are Corporate Carbon Management Practices Reducing Corporate Carbon Emissions?: Are Corporate Carbon Management Practices Reducing Emissions? Corp. Soc. Responsib. Environ. Manag. 257–270. https://doi.org/10.1002/csr.1369.

Fresco, Louise O., 2009. Challenges for food system Adaptation today and tomorrow. Environ. Sci. Pol. Spec. Iss.: Food Sec. Environ. Change 12 (4), 378–385. https://doi.org/10.1016/j.envsci.2008.11.001.

Garnett, Tara, 2011. Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? *Food Policy*, The challenge of global food sustainability 36 (January), S23–S32. https://doi.org/10.1016/j.foodpol.2010.10.010.

"GHG Protocol Agricultural Guidance, 2014. World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). https://ghgprotocol.org/agriculture-guidance.

Giesekam, Jannik, Norman, Jonathan, Garvey, Alice, Betts-Davies, Sam, 2021. Science-based targets: on target? Sustainability 13 (4), 1657. https://doi.org/10.3390/su13041657.

Greene, Suzanne E., 2017. What are we missing? Scope 3 greenhouse gas emissions accounting in the metals and minerals industry. Matériaux Tech. 105 (5–6), 503. https://doi.org/10.1051/mattech/2018014.

Hahn, Rüdiger, Reimsbach, Daniel, Schiemann, Frank, 2015. Organizations, climate change, and transparency: reviewing the literature on carbon disclosure. Organ. Environ. 28 (1), 80–102. https://doi.org/10.1177/1086026615575542.

Harvey, Chelsea, Gronewold, Nathanial, 2019. Greenhouse gas emissions to set new record this year, but rate of growth shrinks. *Science | AAAS*, December 4, 2019. https://www.sciencemag.org/news/2019/12/greenhouse-gas-emissions-year-set-new-record-rate-growth-shrinks.

Hassan, Omaima A.G., Romilly, Peter, 2018. Relations between corporate economic performance, environmental disclosure and greenhouse gas emissions: new insights. Bus. Strat. Environ. 27 (7), 893–909. https://doi.org/10.1002/bse.2040.

Hertwich, Edgar G., Wood, Richard, 2018. The growing importance of scope 3 greenhouse gas emissions from industry. Environ. Res. Lett. 13 (10). https://doi.org/10.1088/1748-9326/aae19a.

Hickmann, Thomas, 2017. Voluntary global business initiatives and the international climate negotiations: a case study of the greenhouse gas Protocol. Journal of Cleaner Production, Experimentation for climate change solutions 169 (December), 94–104. https://doi.org/10.1016/j.jclepro.2017.06.183.

Hsu, Angel, Höhne, Niklas, Kuramochi, Takeshi, Roelfsema, Mark, Amy, Weinfurter, Xie, Yihao, Lütkehermöller, Katharina, et al., 2019. A research roadmap for quantifying non-state and subnational climate mitigation action. Nat. Clim. Change 9 (1), 11–17. https://doi.org/10.1038/s41558-018-0338-z.

Huang, Y. Anny, Weber, Christopher L., Scott Matthews, H., 2009. Categorization of scope 3 emissions for streamlined enterprise carbon footprinting. Environ. Sci. Technol. 43 (22), 8509–8515. https://doi.org/10.1021/es901643a.

Igl, Johannes, Kellner, Florian, 2017. Exploring greenhouse gas reduction opportunities for retailers in fast moving consumer goods distribution networks. Transport. Res. Transport Environ. 50 (January), 55–69. https://doi.org/10.1016/j.trd.2016.10.008.

Interactive: The UNFCCC Negotiating Alliances, 2015. Carbon Brief. November 27, 2015. https://www.carbonbrief.org/interactive-the-negotiating-alliances-at-the-paris-climate-conference.

Jaggi, B., Freedman, M., Martin, C., 2011. Global Warming, Kyoto Protocol, and the Need for Corporate Pollution Disclosures in India: A Case Study. /paper/Global-Warming%2C-Kyoto-Protocol%2C-and-the-Need-for-in-Jaggi-Freedman/3222f3519d772e0b5c46320c3938b655a1819619.

Joselow, Maxine, 2021. Court orders Shell to slash emissions in historic ruling. Sci. Am. May 27, 2021 https://www.scientificamerican.com/article/court-orders-shell-to-slash-emissions-in-historic-ruling/.

Karim, ATM Enayet, Albitar, Khaldoon, Elmarzouky, Mahmoud, 2021. A novel measure of corporate carbon emission disclosure, the effect of capital expenditures and corporate governance. J. Environ. Manag. 290 (July), 112581. https://doi.org/10.1016/j.jenvman.2021.112581.

Kucukvar, Murat, Onat, Nuri C., Abdella, Galal M., Tatari, Omer, 2019. Assessing regional and global environmental footprints and value added of the largest food producers in the world. Resour. Conserv. Recycl. 144 (May), 187–197. https://doi.org/10.1016/j.resconrec.2019.01.048.

Kumar, Praveen, Firoz, Mohammad, 2019. What drives the voluntary environmental reporting (VER): an examination of CDP India firms. J. Environ. Acc. Manag. 7 (March), 45–57. https://doi.org/10.5890/JEAM.2019.03.004.

Li, Dayuan, Huang, Min, Ren, Shenggang, Chen, Xiaohong, Ning, Lutao, 2018. Environmental legitimacy, green innovation, and corporate carbon disclosure: evidence from CDP China 100. J. Bus. Ethics 150 (4), 1089–1104. https://doi.org/10.1007/s10551-016-3187-6.

Li, Mo, Wiedmann, Thomas, Hadjikakou, Michalis, 2020. Enabling full supply chain corporate responsibility: scope 3 emissions targets for ambitious climate change mitigation. Environ. Sci. Technol. 54 (1), 400–411. https://doi.org/10.1021/acs.est.9b05245.

Lohmann, Larry, 2009. "Toward a different debate in environmental accounting: the cases of carbon and cost–benefit. Account. Org. Soc. 34 (3–4), 499–534. https://doi.org/10.1016/j.aos.2008.03.002.

Mahadeo, Jyoti Devi, Oogarah-Hanuman, Vanisha, Soobaroyen, Teerooven, 2011. "Changes in social and environmental reporting practices in an emerging economy (2004–2007): exploring the relevance of stakeholder and legitimacy theories. *Accounting Forum*, Special issue: Social and Environmental Accounting and Accountability 35 (3), 158–175. https://doi.org/10.1016/j.accfor.2011.06.005.

Mahapatra, Santosh K., Tobias, Schoenherr, Jayaram, Jayanth, 2021. "An assessment of factors contributing to firms' carbon footprint reduction efforts. Int. J. Prod. Econ. 235 (May), 108073. https://doi.org/10.1016/j.ijpe.2021.108073.

Mbow, Cheikh, Rosenzweig, Cynthia, Barioni, Luis G., Benton, Tim G., Herrero, Mario, Krishnapillai, Murukesan, Liwenga, Emma, et al., 2019. "Chapter 5: food security - special report on climate change and land." IPCC. https://www.ipcc.ch/site/assets/uploads/2019/08/2f.-Chapter-5_FINAL.pdf.

Meinrenken, Christoph J., 2020. 1, Daniel 2 Chen, Ricardo A. 1 Esparza, Iyer Venkat 1, Sally P. 2 Paridis, Prasad Aruna 3, and New York Whillas Erika 4 1 Columbia University. Carbon Emissions Embodied in Product Value Chains and the Role of Life Cycle Assessment in Curbing Them. https://doi.org/10.1038/s41598-020-62030-x.

Ortas, Eduardo, Gallego-Álvarez, Isabel, Álvarez, Igor, José, M., Moneva, 2015. "Carbon accounting: a review of the existing models, principles and practical applications." in *corporate Carbon and climate accounting*. In: Schaltegger, Stefan, Zvezdov, Dimitar (Eds.), Igor Alvarez Etxeberria, Maria Csutora, and Edeltraud Günther, 77–98. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-27718-9_4.

O'Rourke, D., 2014. The science of sustainable supply chains. Science 344 (6188), 1124–1127. https://doi.org/10.1126/science.1248526.

Patchell, Jerry, 2018. "Can the implications of the GHG protocol's scope 3 standard Be realized? J. Clean. Prod. 185 (June), 941–958. https://doi.org/10.1016/j.jclepro.2018.03.003.

Pinkse, Jonatan, Busch, Timo, 2013. The emergence of corporate carbon norms: strategic directions and managerial implications. Thunderbird Int. Bus. Rev. 55 (6), 633–645. https://doi.org/10.1002/tie.21580.

Qian, Wei, Schaltegger, Stefan, 2017. Revisiting carbon disclosure and performance: legitimacy and management views. Br. Account. Rev. 49 (4), 365–379. https://doi.org/10.1016/j.bar.2017.05.005.

Sanderson, Hans, 2021. Who is responsible for embodied CO2? Climate 9 (3). https://doi.org/10.3390/cli9030041.

Sterner, Thomas, Barbier, Edward B., Bateman, Ian, van den Bijgaart, Inge, , Anne-Sophie Crépin, Edenhofer, Ottmar, Fischer, Carolyn, et al., 2019. Policy design for the anthropocene. Nature Sustainability 2 (1), 14–21. https://doi.org/10.1038/s41893-018-0194-x.

Sullivan, Rory, 2017. Corporate Responses to Climate Change: Achieving Emissions Reductions through Regulation, Self-Regulation and Economic Incentives. Routledge. https://doi.org/10.4324/9781351280006.

Tidy, Martin, Wang, Xiaojun, Hall, Mark, 2016. The role of supplier relationship management in reducing greenhouse gas emissions from food supply chains: supplier engagement in the UK supermarket sector. J. Clean. Prod. 112 (January), 3294–3305. https://doi.org/10.1016/j.jclepro.2015.10.065.

United Nations Climate Change, 2021. Accelerating Supply Chain Decarbonization. June 2, 2021. https://unfccc.int/news/accelerating-supply-chain-decarbonization.

United Nations Environment Programme, 2020. The Emissions Gap Report 2020. https://www.unep.org/emissions-gap-report-2020.

Wendling, Zachary, Emerson, Jay, Esty, Daniel C., Levy, Marc A., De Sherbinin, Alex, 2018. 2018 environmental performance index (EPI). https://doi.org/10.13140/RG.2.2.34995.12328.

"What We Do, 2020. CDP, 2020. https://www.cdp.net/en/info/about-us/what-we-do.

Younis, Hassan, Sundarakani, Balan, 2019a. The impact of firm size, firm age and environmental management certification on the relationship between green supply chain practices and corporate performance. Benchmark Int. J. 27 (1), 319–346. https://doi.org/10.1108/BIJ-11-2018-0363.

Younis, Hassan, Sundarakani, Balan, 2019b. The impact of firm size, firm age and environmental management certification on the relationship between green supply chain practices and corporate performance. Benchmark Int. J. 27 (1), 319–346. https://doi.org/10.1108/BIJ-11-2018-0363.

DATA REFERENCES:

CDP, 2018. GHG Emissions Disclosures.