European Review of Agricultural Economics Vol **50** **(4)** (2023) pp. 1310–1337
doi:https://doi.org/10.1093/erae/jbad018
Advance Access Publication 2 August 2023

Fast and furious: the rise of environmental impact reporting in food systems

Koen Deconinck*, **Marion Jansen and Carla Barisone**
All authors are at the Trade and Agriculture Directorate of the Organisation for Economic Co-operation and Development, Paris, France

Received January 2023; final version accepted May 2023

Abstract

Powerful long-term drivers are increasing both the demand and supply of quantified environmental impact information in food systems. The trend is fast (with many initiatives underway) and furious (presenting a confusing landscape) but has so far received little attention from economists. Better information can inform public and private efforts to reduce environmental pressures. However, the use of different methodologies and reporting requirements could lead to a fragmented landscape. Moreover, there is a risk that poor producers will be disproportionately affected. We discuss the trend, its drivers, impacts and potential pitfalls, as well as the many open research and policy questions.

Keywords: carbon footprint, life-cycle assessment, environmental disclosure, environmental reporting, food supply chains

JEL classification: Q15, A17, Q56

1. Introduction

Food supply chains are about to experience a seismic shift. In the coming decades, firms will increasingly need to report detailed, quantitative information on environmental impacts as a *de facto*, or even *de jure*, requirement for access in many markets. This will include product-level as well as firm-level information and will also cover the impacts of other actors in the firm's supply chain. In turn, this information is likely to serve as the basis for new public and

*Corresponding author: E-mail: koen.deconinck@oecd.org
The authors are not aware of any affiliations, memberships, funding or financial holdings that might be perceived as affecting the objectivity of this review.

private initiatives, such as environmental impact labelling on food products, green public procurement or carbon pricing.

Although environmental impact information could in principle be obtained through direct measurement, currently impacts are mostly estimated or modelled by applying emissions factors to a proxy for economic activity or by using more complex empirical or biophysical models. Different methods can therefore give different results, leading to questions around the most appropriate method and the reliability, and comparability, of claims. As technology improves, it may increasingly become feasible to use direct measurement, including via satellites. At the very least, the methodologies used for the estimation or modelling of emissions will become more accurate over time.

In contrast to other possible disruptions to agri-food trade and markets, such as those caused by climate change or by the rise of meat and dairy alternatives, the trend towards reporting quantified environmental impacts has so far received surprisingly little attention from agricultural economists or policy analysts. Yet, it should. The rise of environmental impact reporting is *fast* (with many initiatives already underway) and *furious* (with a sometimes confusing landscape of organisations, approaches, proposals and methodologies competing for attention). It will have far-reaching consequences along the entire food supply chain, as it may lead to a reorientation of global trade flows and a reorganisation of supply chains. In the best-case scenario, the result will be better information and incentives for farmers, other supply chain actors and consumers to shift towards more sustainable production and consumption patterns. But there are important pitfalls. For example, if countries and companies adopt different methodologies and reporting requirements, the result will be a fragmented landscape, creating high transaction costs and confusion. There is a rationale for coordination by governments to avoid such an outcome and to ensure that initiatives are science based and credible.

Many of the current initiatives by regulators, private-sector actors and civil society stakeholders are at an early stage, but the direction of travel is clear, as powerful long-term drivers are increasing both the demand for this type of information and its supply. Drivers include growing consumer awareness of the environmental pressures emanating from food systems, the growing maturity of methodologies and datasets and an increased emphasis on ‘results-based’ approaches to improve the environmental impact of food systems, complementing existing ‘practice-based’ approaches. In addition, with other sectors moving towards greater sustainability (as reflected in e.g. the growing adoption of electric vehicles and renewable energy), the demand to improve the environmental sustainability of food production will only grow.

This paper discusses the trend towards environmental impact reporting in food systems, its drivers and possible impacts and pitfalls, identifying many open research and policy questions along the way. Carbon footprints will be the main example throughout this paper, as they are the most advanced example of environmental impact reporting. The environmental impacts of food are multidimensional, however (Poore and Nemecek, 2018). Similar approaches can be used for other environmental impacts although methodologies differ in their maturity and robustness (Deconinck and Toyama, 2022); in addition, combining different impact indicators into a summary indicator raises important questions around relative weights.

The remainder of this paper is organised as follows: Section 2 outlines four main levels at which environmental impact reporting in food systems can take place—product, project, firm and country. Section 3 identifies the long-term drivers underpinning the trend towards environmental impact reporting. Section 4 then discusses possible impacts in terms of environmental outcomes and effects on producers, supply chain organisation and trade flows. Section 5 outlines possible pitfalls. These include conceptual, technical and organisational issues. The concluding section reflects on the implications for research and policy.

2. Four levels of reporting

Reporting of environmental impacts related to food systems can take place at several levels. We here distinguish four main levels (product, project, firm and country) and provide a non-exhaustive list of examples to illustrate the trend towards greater reporting.[1]

2.1. Product level

At the product level, environmental impacts can be reported using life-cycle assessment (LCA), which can cover a wide range of environmental impacts, or using related but more narrowly focused methods such as carbon footprints (Hauschild *et al.*, 2018a; Cucurachi *et al.*, 2019). Findings can be used to guide business decision-making, inform policy choices or provide information to consumers (Rajagopal, Vanderghem and MacLean, 2017). Evidence from food LCAs is reviewed by Poore and Nemecek (2018) and Gephart *et al.* (2021).

Product-level approaches are increasingly used to communicate environmental impacts to consumers (Boone *et al.*, 2023). In the United Kingdom, the Foundation Earth initiative issues environmental front-of-pack labels as well as detailed online factsheets for food products, based on LCA. The initiative assigns a letter grade from A+ to G based on a product's performance on several environmental indicators. The initiative is supported by major retailers (e.g. Aldi, Lidl, Tesco and Sainsbury's) and other supply chain actors (e.g. Danone, Unilever, Nestlé and PepsiCo).[2] In France, similar schemes (e.g. Eco-score and Planet-score) were piloted in preparation for public regulations on environmental impact labels for food products (Gouvernement de la République Française, 2022). The European Commission has also been developing the Product Environmental Footprint (PEF) methodology to provide a

1 Other levels of reporting exist, e.g. to quantify emissions related to financial assets and portfolios (Noels and Jachnik, 2022).

2 See https://www.foundation-earth.org/ (accessed 9 January 2023).

uniform approach to environmental impact claims in the European Union (EU) (European Commission, 2021b).[3]

2.2. Project level

Environmental impact reporting can also take place at the project level—for example, in the context of carbon offset schemes. Quantification then focuses on measuring or estimating the amount of Greenhouse Gas (GHG) emissions sequestered or avoided, e.g. in a specific soil carbon sequestration or afforestation project (Gonzalez-Ramirez *et al.*, 2012; Stubbs, Hoover and Ramseur, 2021). In France, the *Label Bas Carbone* is a voluntary government-backed scheme to assess emissions reductions from such projects. Private-sector actors can fund these projects and in turn receive non-tradable offsets.[4] The Australian Emission Reduction Fund can similarly award Carbon Credit Units to projects that enhance soil carbon stocks; these Credit Units can then be sold on the private market or to the government. Similar schemes exist in Alberta, Quebec, California and Spain (Henderson, Frezal and Flynn, 2020; OECD, 2022a). However, because of uncertainties in monitoring, reporting and verification, and concerns around the possible non-permanence of results, these credits are currently not yet accepted in the so-called 'compliance markets' (those that are compliant with national and international law), such as the EU Emissions Trading Scheme or the Clean Development Mechanism. Instead, credits from soil carbon projects tend to be traded in voluntary markets at lower prices (Henderson, Frezal and Flynn, 2020; Henderson *et al.*, 2022).[5]

2.3. Firm level

Firms are increasingly reporting on the environmental impacts associated with their activities—and in many cases also on the impacts of other actors in their supply chains. In 2022, more than 18,600 firms across all sectors disclosed their climate impacts through the CDP platform (formerly the Carbon Disclosure Project), an increase of 42 per cent relative to 2021. In addition, more than 3,900 firms reported water impacts, while more than 1,000 firms reported impacts on forests—in both cases, an increase of about 20 per cent relative to 2021 (CDP, 2022). This includes many agri-food firms. In 2021 (the latest year for which detailed data are available), 116 agricultural commodity firms and 565 firms in the food, tobacco and beverages sector disclosed impacts through CDP although many of those provided incomplete data (Deconinck and Hobeika, 2022).

3 For an introduction to the Product Environmental Footprint approach and related national initiatives in the context of food systems, see Verweij-Novikova, Broekema and Boone (2022).

4 See https://label-bas-carbone.ecologie.gouv.fr/quest-ce-que-le-label-bas-carbone (accessed 13 January 2023).

5 For a discussion of results-based carbon farming in the European Union, see European Commission (2021a).

Firms are facing increasing pressures to report not only emissions from their own operations (referred to as 'Scope 1' in the terminology of the GHG Protocol, a widely used reporting standard) as well as emissions from purchased energy (Scope 2) but also emissions occurring elsewhere in their supply chain, both upstream and downstream (Scope 3). As discussed later, several jurisdictions have been strengthening the requirements for environmental impact reporting by firms. In addition to mandatory disclosure, there is also pressure on companies (by civil society and investors) to provide greater voluntary disclosure of environmental impacts. Farmers are also increasingly asked to report environmental information to suppliers, sometimes in exchange for financial benefits. Suppliers to Tesco, for example, can benefit from more advantageous financing terms based on their environmental performance.[6]

2.4. Country level

Environmental reporting at the country level has historically focused on impacts related to domestic production. Since the Kyoto Protocol (1997), for example, all Annex I countries are required to annually report GHG emissions for all sectors (including agriculture) through National Inventory Reports based on a harmonised methodology (IPCC, 2006, 2019). As with most other country-level environmental indicators, reporting is currently based on where emissions occur, not where final consumption takes place. There is a growing recognition that a consumption-based view (incorporating the effects of international trade) provides an important complementary source of information. For example, Sweden recently became the first country to set a target for consumption-based emissions (Morgan, 2022). Consumption-based indicators can be calculated using detailed inter-country input–output tables (Garsous, 2021). These are likely to be highly relevant for agri-food emissions. Recent estimates based on such an approach suggest that 27 per cent of all agriculture-related (direct and indirect) emissions are embodied in international trade (Hong *et al.*, 2022). In 2019, the UK Committee on Climate Change noted that emissions related to agricultural products were the single largest contributor to imported emissions into the country (CCC, 2019).[7]

The four levels of reporting identified earlier do not operate in isolation, as similar methods and datasets may be used for each. Moreover, organisations developing reporting standards at one level often also develop standards covering other levels. Better information or new insights at one level of reporting may also spur further developments at other levels of reporting. For example, better product-level carbon footprint data received from suppliers would greatly facilitate firms' calculation of their Scope 3 emissions (WBCSD, 2023). Among the four levels of reporting, country-level reporting differs from the others as its findings will be directly relevant mostly to policy audiences,

6 See https://www.edie.net/tesco-links-supplier-financial-support-to-environmental-goals/ (accessed 27 January 2023).

7 For similar consumption-based or trade-based analyses, see e.g. Sandström *et al.* (2018), Pendrill *et al.* (2019) and Helander *et al.* (2021); see Deconinck and Toyama (2022) for a review.

while project-level reporting differs from the others as it is explicitly focused on the *change* in impacts caused by a specific intervention. In the remainder of this paper, we focus on product-level and firm-level reporting.

3. Drivers

As the examples in the previous section show, environmental impact reporting is already occurring in the agri-food sector, even if many initiatives are still at an early stage, and many are voluntary. Yet, reporting on environmental impacts is expected to accelerate in years to come. Several long-term drivers are increasing demand while simultaneously reducing the costs of gathering this information. In addition, some broader trends facilitate these developments.

3.1. The demand for environmental impact information

On the demand side, citizens frequently indicate in surveys that environmental sustainability is important to them (PwC, 2019; Arreza, 2020; BEUC, 2020; Capterra, 2021; EY, 2021; Fabric, 2021; Lusk and Polzin, 2022). So far, however, there remains a major gap between intentions and behaviours (Lusk, 2018; White, Hardisty and Habib, 2019), at least when behaviour is measured as purchases of products with sustainability labels. For example, organic products (which consumers often perceive to be more sustainable) rarely account for more than 10 per cent of food sales in high-income countries despite decades of development and promotion (Deconinck and Hobeika, 2022).[8] Still, products with sustainability claims do seem to be gaining market share (IRI and NYU Stern, 2022), and other sources confirm a growing global awareness of environmental problems (Economist Intelligence Unit, 2021). A 2020 survey among consumers in eight developed economies (France, Germany, Italy, Spain, Sweden, the Netherlands, the United Kingdom and the United States) found strong support for the idea of carbon footprint labelling: in each country, a majority of consumers agreed that it would be a good idea to use such labels, with support rising to 80 per cent or more in France and Italy (Carbon Trust, 2020).[9] In response, retailers and other supply chain actors are increasingly working together to measure, communicate and improve various sustainability criteria.

Investors are also demanding greater information. This may partly reflect retail investors' growing concern about the environment, but the growing demand for information is driven to a large extent by purely fiduciary considerations. More stringent environmental policies, or a growing environmental

8 The actual sustainability performance of organic products is context-specific; see Seufert and Ramankutty, (2017) and Meemken and Qaim, (2018).

9 Recent economic developments such as high rates of inflation (especially for food) have likely affected consumer attitudes. In the United States, for example, 60 per cent of consumers indicated a reduced propensity to buy sustainable products because of inflation (The Conference Board, 2022). However, it remains to be seen to what extent this reflects a permanent shift in consumer attitudes (and behaviours), rather than a temporary effect.

consciousness among consumers, could impose financial costs and reputational damage on firms with a poor environmental performance. Investors thus increasingly demand to be informed about the environmental performance of firms in their portfolio to better screen such risks. An example is the FAIRR Initiative, a network of investors focusing on sustainability issues in the animal protein sector. Members of the network include major asset management firms such as BlackRock or J.P. Morgan and together represent some USD 70 trillion of assets under management. As part of its activities, FAIRR analyses 60 publicly traded animal protein firms on environmental risk factors such as GHG emissions, deforestation, water use and pollution, as well as on other risk factors such as antibiotic use, working conditions and animal welfare. As the organisation makes clear, the underlying motivation is 'to help minimise risks and maximise profits' (FAIRR, 2022).

Government policy is an important source of demand shifts for both firm-level and product-level reporting. In several jurisdictions, firms are already required to report firm-level environmental impacts, especially GHG emissions, and there is a clear trend towards more mandatory disclosure. The new EU Corporate Sustainability Reporting Directive, which entered into force in January 2023, imposes more stringent sustainability reporting requirements on large firms as well as on publicly traded small- and medium-sized enterprises (SMEs). Drafts of the reporting standards for this Directive (which are still under discussion) propose to make it mandatory for those firms to report not only their Scope 1 and 2 emissions but also Scope 3. In the United States, the proposed new rules by the Securities and Exchange Commission would similarly require firms with securities traded in US financial markets to disclose Scope 3 emissions if these are significant or if the firm has set an emissions target covering its Scope 3 emissions (SEC, 2022). Retailers are typically large enough to be covered by the proposed rules for Scope 3 disclosures, which means that a significant share of agri-food emissions in the EU and the United States would be affected by these rules. Government procurement is another driver. In November 2022, the US government proposed the Federal Supplier Climate Risks and Resilience Rule, which would require companies supplying the federal government to disclose their greenhouse gas emissions and climate-related financial risks and to establish science-based emissions reduction targets.[10]

In Europe, governments are also stimulating the demand for product-level environmental information in the agri-food sector. In France, the government is developing an environmental impact labelling scheme for agri-food products. Based on pilot projects conducted in 2020–21, as well as additional scientific research, an independent scientific council concluded that a labelling scheme is feasible and useful (Hélias, van der Werf and Soler *et al.*, 2022); in a report to Parliament, the French government therefore announced that it aimed to introduce a harmonised labelling scheme in 2023

10 See https://www.sustainability.gov/federalsustainabilityplan/fed-supplier-rule.html (accessed 27 January 2023).

(Gouvernement de la République Française, 2022). In March 2023, the European Commission adopted a proposal for a Directive on Green Claims, which would require firms to substantiate claims about the environmental impact of their products using standardised methods (European Commission, 2023).

Finally, civil society organisations have been an important voice demanding greater transparency and accountability (Marquis and Toffel, 2012). Activities by these organisations underpin many of the other demand drivers—e.g. by publicising the negative environmental impacts of major actors in food systems or by lobbying governments for stricter regulations.

3.2. The supply of environmental impact information

In parallel with these demand-side trends, several developments are making it easier to supply information on environmental impacts.

A first factor is the development of standards. Both the GHG Protocol and the International Organization for Standardization (ISO) have standards for carbon footprint calculations at the product, project and firm levels.[11] At the EU level, the PEF and Organization Environmental Footprint methodologies have been developed by the European Commission's Joint Research Centre to provide a harmonised approach (European Commission, 2021b). These generic standards can be complemented by country- and sector-specific standards (WTO, 2021). For agri-food products, for example, the GHG Protocol launched its Agriculture Guidance in 2014 and is currently developing its Land Sectors and Removals Guidance, which is expected to be finalised in 2023. The Livestock Environmental Assessment and Performance Partnership (LEAP) of the Food and Agriculture Organization of the United Nations (FAO) has similarly developed methodological guidance on assessing the environmental performance of livestock sectors.[12] Guidelines on carbon footprint calculation have also been developed by the International Dairy Federation (2022) and the Global Roundtable for Sustainable Beef (2022).

At the firm level, accounting standards are also evolving to provide harmonised guidance on sustainability reporting. In 2021, the International Financial Reporting Standards Foundation, which sets global accounting standards, established the International Sustainability Standards Board (ISSB) to set standards for sustainability disclosures.[13] In October 2022, the ISSB announced that its standards will require Scope 3 emissions reporting.[14] These standards

11 Product-level carbon footprint standards are ISO 14067:2018 and the GHG Protocol Product Life Cycle Accounting and Reporting Standard. Project-level standards are ISO 14064-2:2019 and the GHG Protocol For Project Accounting as well as related guidance. Firm- or organisation-level standards are ISO 14064-1:2018 and the GHG Protocol Corporate Accounting and Reporting Standard. In addition, ISO 14064-3:2019 provides a standard for verification of statements at all three levels (product, project and firm), while standards for LCA (ISO 14040:2006 and ISO 14044:2006) have provided an overall conceptual framework for most other approaches.

12 See https://www.fao.org/partnerships/leap/resources/guidelines/en/ (accessed 7 April 2023).

13 See https://www.ifrs.org/groups/international-sustainability-standards-board/ (accessed 27 January 2023).

14 See https://www.ifrs.org/news-and-events/news/2022/10/issb-unanimously-confirms-scope-3-ghg-emissions-disclosure-requirements-with-strong-application-support-among-key-decisions/ (accessed 27 January 2023).

all concern reporting; other initiatives set standards for target setting. For example, in September 2022, the influential Science-Based Targets Initiative (SBTi) launched its Forest, Land and Agriculture Guidance (FLAG), assisting companies in setting reduction targets covering all land-related emissions.[15] In November 2022, the ISO released its Net Zero Guidelines, which attempt to offer a common understanding of 'net zero' and related concepts.[16]

A second factor is the growing availability of calculation tools to estimate environmental impacts. Reporting standards typically do not prescribe a specific calculation methodology. For example, the GHG Protocol's Corporate Standard merely requires that '[c]ompanies should use the most accurate calculation approach available to them and that is appropriate for their reporting context' (GHG Protocol, 2004). The GHG Protocol's Agricultural Guidance notes that direct measurement is potentially highly accurate but also typically costly and time-consuming, so that in practice three estimation approaches are used: emissions factors applied to proxies for economic activity; empirical models based on statistical relationships between GHG flows and farm-level variables and more complex biophysical process models.[17] As scientific evidence accumulates, these approaches become more refined. Moreover, complex scientifically validated approaches have been translated into simplified calculation tools to facilitate farm-level carbon footprint calculations. One example is the Farmers Assuring Responsible Management (FARM) Environmental Stewardship (ES) tool developed by the National Milk Producers Federation in the United States, based on peer-reviewed research (NMPF, 2020; Asselin-Balençon *et al.*, 2013; Thoma *et al.*, 2013). Another example is COMET-Farm, developed by the US Department of Agriculture.[18] In New Zealand, currently the only country preparing a pricing scheme for agricultural emissions, 11 emissions calculation tools have been approved after an independent assessment (Waka Eke Noa, 2022).[19] The availability of such calculation tools makes it possible to estimate carbon footprints at scale. In Ireland, for example, the Origin Green assurance scheme has developed emissions calculators for beef, dairy, lamb and egg production, in collaboration with the Carbon Trust and Teagasc (the Irish Agriculture and Food Development Authority). To date, some 290,000 farm-level carbon footprints have been calculated (Bia, 2022). Another example is the Cool-Farm tool, originally developed in 2010 by the University of Aberdeen, Unilever and the Sustainable Food Lab and now supported by a growing alliance of leading food supply chain companies. In 2021, the calculation tool had been used in 150 countries by 22,000 users conducting more than 82,000 assessments (Cool Farm, 2022).

15 See https://sciencebasedtargets.org/blog/the-sbtis-flag-guidance-a-groundbreaking-moment-for-addressing-land-related-emissions (accessed 13 January 2023).

16 See https://www.iso.org/netzero (accessed 13 January 2023).

17 These three categories broadly correspond to the IPCC Tier 1, 2 and 3 methodologies for national inventory reporting (IPCC, 2006; GHG Protocol, 2014).

18 See https://www.comet-farm.com/ (accessed 27 January 2023). The COMET-Farm tool is based on the detailed methodological guidance on GHG emissions quantification set out in Eve *et al.* (2014).

19 McConkey *et al.* (2019) review several calculation tools and databases relevant to the beef sector.

A third and related driver is the growing availability of evidence and data that can be used as inputs in such calculations. Carbon footprint calculations and LCAs ideally use primary research to map in detail the physical inputs and outputs of the production process under study (e.g. which energy sources were used and in which quantities). In practice, it is often difficult to collect primary data for all aspects of the life cycle. For example, in assessing the carbon footprint of dairy products along the entire life cycle, it may be necessary to quantify the amounts of fertilisers used in growing animal feed, but primary data may be lacking. In those cases, information from existing datasets can be used to complete the analysis. These datasets are now widespread; for example, the Global LCA Data Access network currently indexes more than 80,000 LCA datasets. The Global Feed LCA Institute maintains harmonised databases of LCAs of animal nutrition ingredients and is currently exploring the possibility of creating harmonised firm-specific LCAs.[20] Another example is Hestia (www.hestia.earth), a joint initiative of Oxford University, the World Wide Fund for Nature and the Login5 Foundation that provides an open-access platform that stores standardised data on agricultural production and its environmental impacts. As the number of food-specific LCAs continues to grow, it also becomes easier to extrapolate. For example, a widely cited study by Poore and Nemecek (2018) synthesised findings from 570 studies covering nearly 40,000 regional- or farm-level assessments in 119 countries to derive estimates of the environmental impacts of agri-food commodities, while Gephart *et al.* (2021) similarly synthesised findings from 61 studies on fish and seafood.[21] In turn, Clark *et al.* (2022) used these results to estimate the environmental impacts of 57,000 food products as found at the retail level. In France, the Agribalyse database (created by the French Agency for Ecological Transition and the National Research Institute for Agriculture, Food and Environment) contains harmonised LCA information on nearly 2,500 food products and is used as the reference dataset for the development of environmental impact labels.[22]

A fourth factor is the emergence of platforms to enable the sharing of environmental impact information. As noted earlier, the number of firms disclosing through the non-profit CDP platform continues to grow exponentially. In addition, there is a burgeoning market for carbon management and accounting software solutions, which make it easier for firms to meet reporting requirements. Other initiatives aim to facilitate the exchange of information between firms to facilitate Scope 3 reporting or LCAs. The Partnership for Carbon Transparency, an initiative of the World Business Council for Sustainable Development, recently released technical specifications for the standardised exchange of carbon emissions data; these specifications create interoperability between different emissions accounting systems (WBCSD, 2022). Other technological solutions may help as well: for example, a better integration of farm

20 See https://globalfeedlca.org/gfli-projects/pilot-branded-data/ (accessed 7 April 2023).

21 A much smaller number of LCAs looks at meat protein alternatives; see Frezal, Nenert and Gay (2022) for a discussion.

22 See https://agribalyse.ademe.fr/ (accessed 30 January 2023).

financial accounts and farm management information systems, in combination with the more widespread use of digital invoices in the sector, would make it easier to transmit information (e.g. on the use of fertilisers or plant protection products) for environmental impact calculations (Poppe, Vrolijk and Bosloper, 2023).

A fifth factor is the development of new technological solutions for directly measuring environmental impacts. For example, while emissions data are currently often self-reported by firms and countries, the Climate TRACE project uses satellites to instead estimate these emissions directly in real time.[23] Satellite estimates are easier for large and stationary sources of pollution such as industrial facilities than for agricultural emissions—although satellites have long been used to monitor deforestation and have recently also been used to identify methane emissions from dairy operations (GHGSat, 2022). In general, environmental impact reporting relies mostly on estimated or modelled emissions, but these technological developments suggest that over time direct measurement might increasingly substitute for such approximations or might at least inform more accurate estimation models.

3.3. Broader trends

In addition to these demand- and supply-side factors, there are some broader trends that facilitate the growth of environmental impact measurement.

One trend is a general shift towards 'supply chain thinking' to tackle sustainability issues in the agri-food sector (Deconinck and Hobeika, 2022). At the EU level, agreement has been reached on a Regulation on Deforestation-Free Supply Chains, while negotiations are ongoing on a Directive on Corporate Sustainability Due Diligence. In parallel, member states are introducing legislation as well. France has had a 'duty of care' law in place since 2017, while the German Supply Chain Due Diligence Act came into effect on 1 January 2023. In the Netherlands, a Bill for Responsible and Sustainable International Business Conduct has been introduced in Parliament in November 2022. The United Kingdom's Environment Act 2021 also contains due diligence requirements for 'forest risk commodities'. While due diligence focuses not only on impacts but also on firms' risk management strategies and processes, the rise in due diligence regulations is an indication that regulators are increasingly using a supply chain lens on sustainability issues (World Economic Forum, 2022). In addition, there are likely to be synergies between disclosure and due diligence (Norton Rose Fulbright, 2022).

A second, related trend is a growing emphasis on supply chain traceability and transparency in the agri-food sector, which not only lets firms create more resilient supply chains but also helps them meet the expectations of regulators and civil society. In addition to firms' own efforts, researchers and civil society have created greater transparency in agri-food supply chains. For example, the Trase initiative builds on a variety of data sources (e.g. customs declarations, shipping records and health inspections) and algorithms to reconstruct

23 See https://climatetrace.org/ (accessed 30 January 2023).

sub-national supply chains of agricultural commodities linked to deforestation (Godar *et al.*, 2015, 2016). In turn, this information has been used to develop more granular LCAs (e.g. Escobar *et al.*, 2020), map deforestation risks of Brazilian beef production (Zu Ermgassen *et al.*, 2020a), study the impact of international trade on biodiversity loss (Green *et al.*, 2019) or evaluate the Zero Deforestation Commitments of major agricultural commodity traders (Zu Ermgassen *et al.*, 2020b).

A third trend is a growing emphasis on measurable outcomes. In the agri-food sector, both private and public approaches to environmental sustainability have historically often focused on prescribing certain practices, e.g. through voluntary sustainability standards or through agri-environmental payments linked to practices rather than outcomes (OECD, 2022b). But outcome-based approaches can offer better incentives. Practice-based approaches often have a ‘binary’ character (e.g. a farmer is certified or not), which limits incentives: farmers who already meet the criteria need not change anything, while farmers far from meeting the requirements may not find it worthwhile to upgrade. Outcome-based approaches, by contrast, could allow for more continuous incentives for improvement, regardless of the starting point, and give more freedom to choose a cost-effective mix of practices to improve outcomes.

Finally, a noteworthy aspect of these developments is the interplay between private and public actors. As noted earlier, retailers and investors are increasingly vocal about the need for greater transparency on the environmental impacts of food, and a growing number of firms are signing up to ambitious mitigation targets set by the SBTi. This includes not only firms active in agri-food production and processing (such as Friesland Campina, which committed to reducing Scope 3 emissions from milk by 33 per cent between 2015 and 2030) but also leading retailers such as Tesco (Scope 3 target of −17 per cent by 2030 relative to 2015), Carrefour (−29 per cent by 2030 relative to 2019) and Ahold Delhaize (−37 per cent by 2030 relative to 2020). In 2017, Walmart initiated Project Gigaton, to reduce or avoid a gigaton of GHG emissions from its supply chains by 2030.[24] Such commitments translate into more stringent requirements on suppliers (and hence, ultimately, farmers), in a process reminiscent of the rise of private standards (Fulponi, 2006; Beghin, Maertens and Swinnen, 2015). Yet, the rise of private initiatives does not occur in a vacuum. As noted earlier, government policy is often directly mandating greater reporting. Even where such rules are not yet in place, the likelihood of stricter environmental regulation in the future may lead many firms to proactively invest in environmental impact reporting (Hickmann, 2017). In turn, as the supply of environmental impact information grows (e.g. through improved datasets and technological solutions), it may become easier

24 See https://corporate.walmart.com/newsroom/2022/04/06/accelerating-climate-action-project-gigaton-marks-key-milestone (accessed 27 January 2023).

for governments to introduce more ambitious mandatory disclosure rules.[25] This interplay between private and public actors is reminiscent of the 'green spiral' identified by Kelsey (2021) in the context of international ozone negotiations or the 'conveyor belt' process for governing net zero described by Hale (2021).

4. Impacts

Greater transparency requirements regarding environmental impacts in food systems will have profound consequences, not only in terms of environmental sustainability but also in terms of the dynamics of trade and supply chains, and impacts on livelihoods. At the moment, only limited empirical evidence exists on these effects. However, economic theory and evidence on related trends lead to the following hypotheses.

If implemented using reliable and comparable methodologies, the move towards environmental impact reporting could be a catalyst for more sustainable consumption and production choices. Product-level information could inform consumer choices (e.g. through labels).[26] The same information could be used by companies to identify hotspots in their production processes and supply chains, informing actions to improve environmental sustainability, including product reformulation (Taufique, Nielsen and Dietz *et al.*, 2022).[27] Detailed product-level information could also form the basis for other policy interventions, e.g. green public procurement or fiscal measures. Environmental impact reporting at the firm level could be used to benchmark companies against their peers and to monitor firms' commitments to climate mitigation targets, creating greater accountability. Country-level information could be used to track the effectiveness of policies to stimulate more sustainable production and consumption choices.

To understand the potential impact of better information, consider the benchmark of a Pigouvian carbon tax under perfect information. Such a tax would in theory achieve optimal mitigation through several 'margins of adjustment'.[28] First, product categories with an above-average carbon footprint would become more expensive, inducing consumers to shift towards lower-emissions categories (e.g. from ruminant products to non-ruminant products or meat alternatives). Second, within each category, it would favour producers with a lower carbon footprint, leading to an additional shift towards lower-emissions producers (e.g. from higher- to lower-emissions dairy producers). Third, it would incentivise all actors along the food supply chain to change

25 For example, the proposed US Federal Supplier rule discussed earlier mentions the standards firms would need to follow for reporting and target-setting obligations. These are the GHG Protocol Corporate Standard, the Task Force on Climate-Related Financial Disclosures standard, CDP and the SBTi.

26 Regarding the possible effects of such labels on consumer behaviour, see e.g. Soler *et al.* (2021), Potter *et al.* (2022), De Bauw *et al.* (2021) and Potter *et al.* (2023).

27 There is some evidence that nutritional front-of-pack labels can incentivise product reformulation; see Roberto *et al.* (2021).

28 See Cherniwchan, Copeland and Taylor (2017) for a related argument about different levers for reducing average industry-level emissions.

techniques to lower their emissions, including through research and development (R&D) (e.g. by further developing feed additives to reduce enteric fermentation).

These different margins are highly relevant in the agri-food sector. Evidence from LCAs shows that some product categories have higher environmental footprints than others but also that there exists a significant heterogeneity (Deconinck and Toyama, 2022). For example, Poore and Nemecek (2018) find that globally, and across all agricultural commodities, 25 per cent of production is responsible for more than half of the environmental impact. But even among producers in the same growing regions, they find high variability. Other research by Trase (2020) finds that within a country, a minority of production regions usually accounts for a large share of deforestation risks: for example, more than half of the deforestation risk of Brazilian soy exports occurs in just 1 per cent of soy-producing municipalities, while in Indonesia, 6 per cent of palm-oil-producing districts account for half the deforestation. As Poore and Nemecek (2018) point out, these skewed impacts represent opportunities for targeted mitigation.

Information provision by itself may not provide a sufficient incentive to change behaviour, but better information provides the essential infrastructure on which other policies, including Pigouvian taxes, could be built. However, this requires a sufficiently fine-grained system of environmental impact reporting: if average values by product category or by country are used instead, incentives will be blunted. Even if estimated or modelled impacts remain the norm, this argues for using a sufficiently detailed and context-specific approach, with frequent updates to estimation tools to take into account technological progress.

The precise impacts will of course depend on the specifics of the policies built on the new data infrastructure. For example, the Organisation for Economic Co-operation and Development analysis on climate mitigation policies in agriculture has shown that effects on global food security and livelihoods differ considerably when abatement payments are used instead of emissions taxes (OECD, 2019) although these approaches would probably have similar information requirements. In general, understanding the dynamics of global agri-food trade will be critical in evaluating impacts (Henderson and Verma, 2021; Gruère *et al.*, 2023). For example, more stringent requirements in one market might lead to a 'reshuffling' of trade flows, whereby low-impact products are sent to the more stringent market while high-impact products are sent to less stringent markets, with only limited improvements in global environmental impacts.

An important concern is that a shift towards more sustainable purchase decisions by consumers, firms or governments in high-income countries (whether due to taxes, labels or other initiatives) might disproportionately affect producers in low- and middle-income countries, as these often have higher emissions intensities. These producers may also face greater barriers in demonstrating their carbon footprint (WTO, 2021). Moreover, the rise of environmental impact reporting could also affect bargaining power and value sharing within food supply chains, including through a greater role for actors such as third-party verification bodies and technology or data providers.[29] These questions around inclusion/exclusion and bargaining power are reminiscent of the literature on the effects of quality, safety and sustainability standards in global agri-food supply chains (e.g. Swinnen, 2007; Minten, Randrianarison and Swinnen, 2009; Henson and Humphrey, 2010; Meemken *et al.*, 2021).[30]

On the other hand, the rise of environmental impact reporting may also provide a strong incentive for supply chain actors in high-income countries to help reduce emissions in low- and middle-income countries. Indeed, it is possible that the growing emphasis on life-cycle or Scope 3 impacts will lead to greater vertical coordination in global supply chains, for example, because retailers, processors or traders see an opportunity to invest in reducing the environmental impacts of farmers to ensure themselves of a steady supply of products with a low environmental impact. This may involve more stringent requirements imposed on farmers by other supply chain actors. A similar reorganisation of supply chains occurred in response to the growing demand for quality and safety attributes of food products (Beghin, Maertens and Swinnen, 2015; Swinnen *et al.*, 2015). Technical assistance from high-income countries could also help to develop the necessary institutional infrastructure to facilitate environmental impact reporting in low- and middle-income countries (WTO, 2021).

5. Pitfalls

The discussion in the previous section presupposed reliable measurements and comparable methodologies, but of course, these cannot be taken for granted. Indeed, there are several conceptual, technical and organisational pitfalls that need to be avoided.

Conceptually, environmental impact assessments involve a large number of decisions, for example, on which environmental impacts and which stages of the life cycle are considered in scope, how environmental impacts should be allocated when a production process has multiple outputs (e.g. when oilseeds are crushed, resulting in protein meal and vegetable oil), which approximations will be used for hard-to-measure impacts and so on (Deconinck and Toyama, 2022). One challenge is that methods and datasets are not equally well developed for all relevant environmental impacts, and some methodologies have been criticised for not covering important impacts. For example, the EU PEF methodology does not capture soil carbon and on-farm biodiversity impacts well (Hélias, van der Werf and Soler *et al.*, 2022). When several

29 On bargaining and value sharing in food value chains more generally, see Swinnen and Vandeplas (2010) and Bonanno, Russo and Menapace (2018). On the digitalisation of agriculture, see McFadden *et al.* (2022); on data governance questions, see Jouanjean *et al.* (2020).

30 These effects also raise the broader question of social sustainability in food supply chains. While LCA has traditionally focused on environmental impacts, there is recent work to extend this to social issues (Moltesen *et al.*, 2018). However, there is much less agreement on relevant indicators and data sources. For a systematic review of the academic literature on social sustainability in food supply chains, see Desiderio *et al.* (2022).

environmental dimensions are covered (as is the case in the PEF, which covers 16 dimensions including climate change, water use, ozone depletion and ecotoxicity), an important question is how these can be weighed to arrive at an overall score; any weighting scheme inevitably involves value judgements (Rosenbaum *et al.*, 2018).

Another important conceptual question is whether to take an *attributional* or a *consequential* lens. Attributional approaches offer a snapshot of impacts at a point in time, while consequential approaches ask what the consequences would be of a marginal change (e.g. increasing output by one unit), taking into account economic and behavioural feedback and substitution effects. The vast majority of approaches in food systems are attributional, which obscures e.g. indirect land use change implications; however, consequential approaches are more complicated and require additional assumptions (Rajagopal, 2014).

In addition to these conceptual questions, there are technical challenges in measuring environmental impacts in the agri-food sector—and these challenges are likely greater than for other sectors. As mentioned earlier, environmental performance in the agri-food sector is highly heterogeneous, which suggests that farm-level estimates are to be preferred over the use of averages (Poore and Nemecek, 2018). Yet this would imply gathering information from many more actors than are covered in other sectors: fewer than 18,000 industrial installations report their emissions under the EU Emissions Trading Scheme (ETS), but there are more than nine million farms in the EU. Even if detailed quantification efforts were restricted to large farms with an output greater than EUR 250,000, this would still leave nearly 300,000 farms, an order of magnitude greater than the number of entities in the EU ETS.[31] Moreover, food systems are global, and a significant share of environmental impacts occur abroad, often in low- and middle-income countries where transaction costs in gathering reliable data are higher.

These technical challenges are real but perhaps not as daunting as they seem. First, as environmental impacts are typically estimated or modelled, in-person farm visits are not always necessary. When reliable models are available, existing farm-level data can often be used, for example, from environmental data farmers are already required to report to the government in some countries. Technological advances and growing data availability will again facilitate this. The example of the Irish Origin Green scheme demonstrates that it is indeed possible to calculate carbon footprints at scale.

There are also some practical workarounds that could provide reasonable estimates at lower transaction costs. One possibility is to develop a set of 'rebuttable' default values (McAusland and Najjar, 2015; Heine, Hayde and Faure, 2021). A standard database could be used as the reference for the environmental impacts of a product, unless firms provide their own LCA.[32]

31 Eurostat, 'Farms and Farmland in the European Union – statistics', available at https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Farms_and_farmland_in_the_European_Union_-_statistics#Farms_in_2020 (accessed 9 January 2023).

32 A related approach is to allow for 'semi-specific' approaches, where default values from a standard database are adjusted on the basis of some easily verifiable criteria involving high-impact

Especially where fiscal incentives are linked to product-level environmental impacts, this could provide an incentive for firms to invest in LCAs, leading to a greater evidence base over time. This approach could strike a balance between the need for fine-grained data (to incentivise change on all three margins of adjustment discussed earlier) and the objective of keeping transaction costs low.

However, greater difficulties may arise on the organisational side. A major risk is that the trend towards greater environmental impact reporting will result in a proliferation of approaches, leading to a fragmented landscape and high transaction costs. In the financial sector, the growing demand for responsible investment products has led to competing ratings of firms' Environmental, Social and Governance performance, with ratings from different providers often poorly correlated with each other, creating confusion (Boffo *et al.*, 2020). In an agri-food context, the risk is not only that countries adopt different requirements (e.g. for mandatory reporting) but also that private actors such as retailers impose different systems on their suppliers, leading to unnecessary transaction costs.

It is useful to distinguish here between three levels (WTO, 2021). The first is the level of *standards*, which define what needs to be measured and how. The second is the level of *verification*, i.e. of showing the reliability of an environmental impact estimate. The third is the level of *communication* of claims (e.g. through labels).

Ideally, countries would align on internationally harmonised standards for environmental impact reporting. This would reduce transaction costs and would also remove a potential source of trade frictions, as the Technical Barriers to Trade Agreement considers that regulations based on international standards are a priori not unnecessarily trade restricting (WTO, 2021). As noted earlier, several standards for measuring emissions and carbon footprints currently exist, including the GHG Protocol and ISO standards. But frictions are probably less likely to come from these high-level reporting standards and more from the specific calculation methods. Reporting standards tend to be quite similar; for example, the GHG Protocol standard on firm-level reporting was used as a starting point in developing the corresponding ISO standard, resulting in similar requirements (Hickmann, 2017). But standards leave room for different calculation methods, and this is where disagreements may emerge. On the one hand, calculation methods should be tailored to country-specific contexts (such as the FARM ES tool for the US dairy sector or the New Zealand emissions calculators mentioned earlier). On the other hand, this raises the question of international recognition of calculation methods and results. For example, producers could argue that foreign competitors' carbon footprints were calculated using methods that are too flattering.

Firms may be increasingly asked to demonstrate the reliability of their environmental impact estimates (e.g. carbon footprints), for instance through

actions—for example, on the type of packaging or mode of transport (Hélias, van der Werf and Soler *et al.*, 2022).

verification by an accredited third party. Such verification is already required for emissions reported under the EU Emissions Trading Scheme and is also recommended (but not required) for firms disclosing on the CDP platform. WTO rules promote harmonisation of verification approaches through international standards and encourage countries to accept the results of assessments performed by other countries. This could be done through mutual recognition agreements, accreditation of foreign conformity assessment bodies or acceptance of a Supplier's Declaration of Conformity, among other approaches (WTO, 2021).[33] However, third-party verification does not evaluate the specific calculation tool used.

WTO rules also provide guidance on communication of environmental impact claims. For example, when governments introduce labelling requirements, these should be based on international guidance where it exists; should not be discriminatory; should not create unnecessary barriers to trade and may need to be notified to the WTO (WTO, 2021).

Addressing these issues should happen as soon as possible, as uncertainty itself imposes costs on firms and reduces trade (Novy and Taylor, 2020). Coordination among countries, for example through trade agreements, could address some of the risks associated with fragmentation. For example, countries could agree on the reporting standards and calculation methods they will consider equivalent. However, this still leaves the possibility of private actors adopting different requirements. The public sector could play a role by facilitating harmonisation of private-sector standards or by introducing a public standard (Rousset *et al.*, 2015).

6. Conclusion

Economic development goes hand in hand with a transformation of food supply chains (Barrett *et al.*, 2022). Historically, this has involved a lengthening of supply chains, a move from labour-intensive to more capital-intensive methods, and greater scale and specialisation, including through the emergence of supermarkets, fast food chains and third-party logistics providers. In recent decades, food supply chains witnessed a growth in contracts, private standards and vertical coordination as supply chain actors responded to a growing demand for food safety and quality and increasingly also other attributes such as social and environmental characteristics (Beghin, Maertens and Swinnen, 2015; Swinnen *et al.*, 2015; Meemken *et al.*, 2021). Consequently, a large literature has explored the role of voluntary sustainability standards prevailing so far in agro-food supply chains (Meemken *et al.*, 2021; Traldi, 2021). A new phase has now started, characterised by environmental impact reporting.

As we have outlined in this paper, such impact reporting can take place at the level of a product, project, firm or country. While many initiatives are currently in an early stage, their development and uptake are accelerating in

33 In addition, trade facilitation will be important, as firms may face new documentary requirements at the border. Previous research has shown that streamlining procedures at the border can facilitate trade, especially for SMEs (Lopez González and Sorescu, 2019).

response to growing demand for this information and a growing supply of standards, calculation tools, datasets and technologies to deliver it. Accounting and reporting standards play a central role in these dynamics.

Under ideal conditions, the rise of environmental impact reporting would herald an era of greater transparency in agri-food supply chains, which would enable more sustainable production and consumption choices. Yet the same development may lead to a reshuffling of trade flows and a reorganisation of supply chains, with possibly adverse consequences on small-scale producers in low- and middle-income countries. In addition, there are several pitfalls that need to be avoided in setting up a reliable system of environmental impact reporting. These include conceptual problems (e.g. which impacts to include), technical questions (e.g. how to measure or estimate these impacts, given the large number of producers) and organisational questions (e.g. how to avoid a fragmentation of approaches leading to high transaction costs).

There are numerous open research questions.[34] First, there are still important evidence gaps regarding environmental impacts of certain products, life-cycle stages and geographic regions (Halpern *et al.*, 2019; Deconinck and Toyama, 2022). It is also unclear what the optimal institutional setup is to measure and communicate environmental impacts and how to obtain accurate data while avoiding excessive transaction costs. Further work should explore the relative performance of the various calculation tools and datasets in this regard.

Second, it is unclear at the moment how these developments will affect producers and consumers. For example, will farmers with lower environmental impacts be able to reap a price premium, and will producers with a worse performance be excluded from supply chains? How will the organisation of value chains evolve, and how will this in turn affect relative bargaining power? To what extent will consumers change their consumption patterns in response to environmental labelling? To what extent will food manufacturers reformulate products to achieve lower impacts?

Third, there are questions around synergies and trade-offs with other policies and policy objectives. For example, to what extent could existing traceability requirements for food safety be 'repurposed' to facilitate environmental impact reporting? Could environmental impact reporting pave the way for social sustainability reporting? What is the scope for harmonisation or mutual recognition of approaches to prevent trade frictions? Will environmental impact reporting act as a substitute, or a complement, for existing practice-based schemes (e.g. voluntary sustainability standards)?

Agricultural economists are well placed to fill these evidence gaps, in particular since many of the questions echo those of earlier transformations of food supply chains, notably the growth of standards (Beghin, Maertens and Swinnen, 2015; Meemken *et al.*, 2021).

At the same time, the 'fast and furious' rise of environmental impact reporting will continue apace, and given the urgency of climate change mitigation,

34 See also Sellare *et al.* (2022), who outline research priorities regarding due diligence approaches.

policymakers will inevitably need to act before all scientific uncertainties have been resolved. In addition to funding more research, policymakers may therefore want to engage with domestic stakeholders (including farmers, food supply chain actors, investors, scientists and civil society) and with their counterparts abroad to get a clear understanding of the initiatives underway. This can help avoid an unnecessary duplication of efforts, can prevent needless transaction costs due to diverging approaches and can facilitate peer learning. Where policymakers encounter a potential fragmentation of private-sector approaches, there might be scope to encourage harmonisation or to introduce a public standard. While most attention currently goes to carbon footprints, policymakers should also keep in mind that many other environmental impacts matter in food systems, so that initiatives should ideally have the flexibility to report on these other impacts as well.

A key focus of policymakers should be on balancing the need for granular information with the need to keep monitoring costs low. Several options exist. Governments can invest in a ‘generic’ database (such as the French Agribalyse database) to be used as a default in the absence of more precise data. Governments can also stimulate the development of simplified yet rigorous calculation methods to allow carbon footprint calculations at scale. Several voluntary sustainability initiatives such as Rainforest Alliance, Bonsucro or the Roundtable on Sustainable Palm Oil now require the annual quantification of greenhouse gas emissions and sequestration (Cool Farm, 2022); governments could work with such sustainability initiatives as well as with other farm assurance schemes (such as Origin Green in Ireland) or farm organisations (such as the National Milk Producers Federation in the United States) to help them conduct farm-level carbon footprint calculations at scale. Working with the private sector, ideally an approach can be found where farmers and other supply chain actors need only calculate and report their impacts once and where this information is then transmitted along the supply chain, including across borders.

Finally, policymakers should also consider how new initiatives will affect poor, small-scale producers (especially in low- and middle-income countries) and should explore what can be done to minimise negative impacts. For example, technical assistance could be provided to help these producers measure and reduce their emissions to prevent them from being excluded from global value chains.

Acknowledgements

The authors gratefully acknowledge helpful discussions with Ellie Avery, Annelies Deuss, Matteo Fiorini, Clara Frezal, Grégoire Garsous, Céline Giner, Guillaume Gruère, Ben Henderson, Lee Ann Jackson, Shivani Kannabhiran, Alan Matthews, Sébastien Miroudot, Evdokia Moise, Julia Nielson, Enxhi Tresa and Hugo Valin. The authors wish to express their special thanks to Koen Boone for numerous thought-provoking discussions on this topic. The opinions expressed and arguments employed herein are solely those of the authors and do not necessarily reflect the official views of the Organisation for Economic Co-operation and Development or of its member countries.

References

Arreza, J. (2020). Ninety per cent of Australian consumers want sustainable products. The Fifth State. https://thefifthestate.com.au/homeandlifestyle/consumers/ninety-per-cent-of-australian-consumers-want-sustainable-products/. Accessed 20 January 2023.

Asselin-Balençon, A. C., Popp, J., Henderson, A., Heller, M., Thoma, G. and Jolliet, O. (2013). Dairy farm greenhouse gas impacts: a parsimonious model for a farmer's decision support tool. *International Dairy Journal* 31: S65–S77.

Barrett, C. B., Reardon, T., Swinnen, J., Zilberman, D. (2022). Agri-food value chain revolutions in low-and middle-income countries. *Journal of Economic Literature* 60(4): 1316–1377.

Beghin, J. C., Maertens, M. and Swinnen, J. (2015). Nontariff measures and standards in trade and global value chains. *Annual Review of Resource Economics* 7: 425–450.

BEUC. (2020). One bite at a time: consumers and the transition to sustainable food. https://www.beuc.eu/publications/beuc-x-2020042_consumers_and_the_transition_to_sustainable_food.pdf. Accessed 20 January 2023.

Bia, B. (2022). Origin Green – Progress Update Report 2021. https://www.origingreen.ie/globalassets/origin-green/progress-update-report/bord-bia—origin-green-2021-progress-update-report.pdf. Accessed 19 January 2023.

Boffo, R. and Patalano, R. (2020). ESG investing: practices, progress and challenges. OECD Paris. https://www.oecd.org/finance/esg-investing.htm. Accessed 16 June 2023.

Bonanno, A., Russo, C. and Menapace, L. (2018). Market power and bargaining in agrifood markets: a review of emerging topics and tools. *Agribusiness* 34: 6–23.

Boone, J. A., Broekema, R., van Haaster-de Winter, M. A., Verweij-Novikova, I. and Adema, H. (2023). LCA-based labelling systems: game changer towards more sustainable food production and consumption across Europe. Wageningen Economic Research; No. 2023-005. Wageningen Economic Research. https://edepot.wur.nl/587264. Accessed 7 April 2023.

Capterra (2021). Sustainability: consumers care, but don't necessarily act. https://www.capterra.ca/blog/2229/sustainability-in-canada-consumers. Accessed 20 January 2023.

Carbon Trust (2020). Product carbon footprint labelling – consumer research 2020. https://www.carbontrust.com/our-work-and-impact/guides-reports-and-tools/product-carbon-footprint-labelling-consumer-research. Accessed 20 January 2023.

CCC (2019). Reducing UK emissions: 2019 progress report to Parliament. London: Committee on Climate Change. www.theccc.org.uk/publication/reducing-uk-emissions-2019-progress-report-to-parliament. Accessed 20 January 2023.

CDP (2022). The A List 2022. https://www.cdp.net/en/companies/companies-scores. Accessed 23 January 2023.

Cherniwchan, J., Copeland, B. R. and Taylor, M. S. (2017). Trade and the environment: new methods, measurements, and results. *Annual Review of Economics* 9: 59–85.

Clark, M., Springmann, M., Rayner, M., Scarborough, P., Hill, J., Tilman, D., Harrington, R. A. (2022). Estimating the environmental impacts of 57,000 food products. *Proceedings of the National Academy of Sciences* 119: e2120584119.

The Conference Board (2022). Economic downturn creates additional hurdle for purchasing sustainable products, requiring a rethink of pricing approach. https://www.conference-board.org/topics/consumers-attitudes-sustainability/economic-downturn-creates-additional-hurdle-for-purchasing-sustainable-products. Accessed 7 April 2023.

Cool Farm (2022). Cool Farm Annual Report – Calendar Year 2021. https://coolfarmtool.org/wp-content/uploads/2022/04/Annual-Report-Calendar-Year-2021.pdf. Accessed 23 January 2023.

Cucurachi, S., Scherer, L., Guinée, J. and Tukker, A. (2019). Life cycle assessment of food systems. *One Earth* 1: 292–297.

De Bauw, M., Matthys, C., Poppe, V., Franssens, S. and Vranken, L. (2021). A combined Nutri-Score and 'Eco-Score' approach for more nutritious and more environmentally friendly food choices? Evidence from a consumer experiment in Belgium. *Food Quality and Preference* 93: 104276.

Deconinck, K. and Hobeika, M. (2022), "Improving environmental outcomes along food supply chains: a review of initiatives and their effectiveness", OECD Food, Agriculture and Fisheries Papers, No. 186, Paris: OECD Publishing.

Deconinck, K. and Toyama, L. (2022), "Environmental impacts along food supply chains: methods, findings, and evidence gaps", OECD Food, Agriculture and Fisheries Papers, No. 185, OECD Publishing, Paris.

Desiderio, E., García-Herrero, L., Hall, D., Segrè, A. and Vittuari, M. (2022). Social sustainability tools and indicators for the food supply chain: a systematic literature review. *Sustainable Production and Consumption* 30: 527–540.

Economist Intelligence Unit (2021). An eco-wakening: measuring global awareness, engagement and action for nature. https://explore.panda.org/eco-wakening. Accessed 5 January 2023.

Escobar, N., Tizado, E. J., Zu Ermgassen, E. K., Löfgren, P., Börner, J. and Godar, J. (2020). Spatially explicit footprints of agricultural commodities: mapping carbon emissions embodied in Brazil's soy exports. *Global Environmental Change* 62: 102067.

European Commission (2021a). Setting up and implementing result-based carbon farming mechanisms in the EU: Technical Guidance Handbook, Publications Office of the European Union.

European Commission (2021b). Understanding product environmental footprint and organisation environmental footprint methods, Joint Research Centre of the European Commission. https://ec.europa.eu/environment/eussd/smgp/pdf/EF%20simple%20guide_v7_clen.pdf. Accessed 6 January 2023.

European Commission (2023). Green claims: new criteria to stop companies from making misleading claims about environmental merits of their products and services. https://environment.ec.europa.eu/topics/circular-economy/green-claims_en. Accessed 11 April 2023.

Eve, M., Pape, D., Flugge, M., Steele, R., Man, D., Riley-Gilbert, M. and Biggar, S., (Eds), (2014). Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory. Technical Bulletin Number 1939. Washington, DC: Office of the Chief Economist, U.S. Department of Agriculture. 606. https://www.usda.gov/sites/default/files/documents/USDATB1939_07072014.pdf. Accessed 11 April 2023.

EY (2021). The global pandemic is far from over, but consumers are ready to move on, according to the latest EY Future Consumer Index. https://www.ey.com/en_gl/consumer-productsretail/asconsumers-move-on-stay-close. Accessed 20 January 2023.

Fabric (2021). The State of Sustainability in Japan 2021: how consumers think and act, and how brands can stay one step ahead. https://fbrc.co/reports/fabric-state-of-sustainability-in-japan-2021-ENv3.0.pdf. Accessed 20 January 2023.

FAIRR (2022). Making the Argument. https://www.fairr.org/about-fairr/making-the-argument/. Accessed 5 January 2023.
Frezal, C., Nenert, C. and Gay, H. (2022). Meat protein alternatives: opportunities and challenges for food systems' transformation. OECD Food, Agriculture and Fisheries Papers, No. 182. Paris: OECD Publishing.
Fulponi, L. (2006). Private voluntary standards in the food system: the perspective of major food retailers in OECD countries. *Food Policy* 31: 1–13.
Garsous, G. (2021). Developing consumption-based emissions indicators from Agriculture, Forestry and Land-use (AFOLU) activities. OECD Food, Agriculture and Fisheries Papers, No. 171. Paris: OECD Publishing.
Gephart, J. A., Henriksson, P. J., Parker, R. W., Shepon, A., Gorospe, K. D., Bergman, K. … Troell, M. (2021). Environmental performance of blue foods. *Nature* 597: 360–365.
GHG Protocol (2014). GHG Protocol Agricultural Guidance. https://ghgprotocol.org/agriculture-guidance. Accessed 26 June 2023.
GHGSat (2022). Cow burps seen from space. May 2, 2022 press release. https://www.ghgsat.com/en/newsroom/cow-burps-seen-from-space/. Accessed 16 June 2023.
Global Roundtable for Sustainable Beef (2022). GRSB launches the Beef Carbon Footprint Guideline to support consistency in emissions reporting worldwide. https://grsbeef.org/2022/03/news-release-grsb-launches-beef-carbon-footprint-guideline/. Accessed 7 April 2023.
Godar, J., Persson, U. M., Tizado, E. J. and Meyfroidt, P. (2015). Towards more accurate and policy relevant footprint analyses: tracing fine-scale socio-environmental impacts of production to consumption. *Ecological Economics* 112: 25–35.
Godar, J., Suavet, C., Gardner, T. A., Dawkins, E. and Meyfroidt, P. (2016). Balancing detail and scale in assessing transparency to improve the governance of agricultural commodity supply chains. *Environmental Research Letters* 11: 035015.
González-Ramírez, J., Kling, C. L. and Valcu, A. (2012). An overview of carbon offsets from agriculture. *Annual Review of Resource Economics* 4: 145–160.
Gouvernement de la République Française (2022). Government report to Parliament: environmental labelling for food products – Overview and key findings (January 2022). https://expertises.ademe.fr/sites/default/files/assets/documents/environnemental-labelling-food-products-government-report-parliament.pdf. Accessed 16 June 2023.
Green, J. M., Croft, S. A., Durán, A. P., Balmford, A. P., Burgess, N. D., Fick, S., Gardner, T. A., Godar, J., Suavet, C., Virah-Sawmy, M., Young, L. E. and West, C. D. (2019). Linking global drivers of agricultural trade to on-the-ground impacts on biodiversity. *Proceedings of the National Academy of Sciences* 116: 23202–23208.
Greenhouse Gas Protocol (2004). A corporate accounting and reporting standard – revised edition. Greenhouse Gas Protocol. https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf. Accessed 18 January 2023.
Gruère, G., Migliaccio, E., Ellis, E., Kodama, W., Roffredi, L. and Vanisova, V. (2023). Pursuing higher environmental goals for agriculture in an interconnected world: Climate change and pesticides. OECD Food, Agriculture and Fisheries Papers, No. 193. Paris: OECD Publishing.
Hale, T. (2021). Governing net zero: the conveyor belt. Blavatnik School of Government Policy Memo. Oxford University. https://www.bsg.ox.ac.uk/research/publications/governing-net-zero-conveyor-belt. Accessed 7 April 2023.
Halpern, B. S., Cottrell, R. S., Blanchard, J. L., Bouwman, L., Froehlich, H. E., Gephart, J. A., Sand Jacobsen, N., Kuempel, C. D., McIntyre, P. B., Metian, M. and Moran, D. D. (2019). Putting all foods on the same table: achieving sustainable food systems

requires full accounting. *Proceedings of the National Academy of Sciences* 116(37): 18152–18156.

Hauschild, M., Rosenbaum, R. K. and Olsen, S. eds. (2018a). *Life Cycle Assessment: Theory and Practice*. Cham: Springer International Publishing.

Hauschild, M. Z., Bonou, A. and Olsen, S. I. (2018b). Life cycle interpretation. In: M. Z. Hauschild, R. K. Rosenbaum and S. Olsen (eds), *Life Cycle Assessment*. Cham: Springer, 323–334.

Heine, D., Hayde, E. and Faure, M. (2021). Chapter 6: Letting Commodity Tax Rates Vary with the Sustainability of Production. World Bank (2021), Designing Fiscal Instruments for Sustainable Forests. Washington, DC: The World Bank Group. https://www.climateinvestmentfunds.org/sites/cif_enc/files/knowledgedocuments/designing_fiscal_instruments.pdf. Accessed 25 January 2023.

Helander, H., Bruckner, M., Leipold, S., Petit-Boix, A. and Bringezu, S. (2021). Eating healthy or wasting less? Reducing resource footprints of food consumption. *Environmental Research Letters* 16: 054033.

Hélias, A., van der Werf, H. M. G., Soler, L. G. *et al.* (2022). Implementing environmental labelling of food products in France. *The International Journal of Life Cycle Assessment* 27:926–931.

Henderson, B. *et al.* (2022). Soil carbon sequestration by agriculture: Policy options. OECD Food, Agriculture and Fisheries Papers, No. 174. Paris: OECD Publishing.

Henderson, B., Frezal, C. and Flynn, E. (2020). A Survey of GHG Mitigation Policies for the Agriculture, Forestry and Other Land Use Sector. OECD Food, Agriculture and Fisheries Papers, No. 145. Paris: OECD Publishing.

Henderson, B. and Verma, M. (2021). Global assessment of the carbon leakage implications of carbon taxes on agricultural emissions. OECD Food, Agriculture and Fisheries Papers, No. 170. Paris: OECD Publishing.

Henson, S. and Humphrey, J. (2010). Understanding the complexities of private standards in global agri-food chains as they impact developing countries. *The Journal of Development Studies* 46: 1628–1646.

Hickmann, T. (2017). Voluntary global business initiatives and the international climate negotiations: a case study of the Greenhouse Gas Protocol. *Journal of Cleaner Production* 169: 94–104.

Hong, C., Zhao, H., Qin, Y., Burney, J. A., Pongratz, J., Hartung, K., Liu, Y., Moore, F. C., Jackson, R. B., Zhang, Q. and Davis, S. J. (2022). Land-use emissions embodied in international trade. *Science* 376: 597–603.

International Dairy Federation. (2022). The IDF global carbon footprint standard for the dairy sector. Bulletin of the IDF n 520/2022, IDF, Brussels.

IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change. https://www.ipcc-nggip.iges.or.jp/public/2006gl/. Accessed 23 January 2023.

IPCC (2019). 2019 Refinement to the 2006 IPCC guidelines for national greenhouse gas inventories. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/. Accessed 23 January 2023.

IRI and NYU Stern (2022). Sustainability and the consumer. https://www.iriworldwide.com/IRI/media/Library/IRI-NYU-Sustainability-2022-PDF.pdf. Accessed 5 January 2023.

Jouanjean, M. *et al.* (2020). Issues around data governance in the digital transformation of agriculture: the farmers' perspective. OECD Food, Agriculture and Fisheries Papers, No. 146. Paris: OECD Publishing.

Kelsey, N. (2021). International ozone negotiations and the green spiral. *Global Environmental Politics* 21: 64–87.

López González, J. and Sorescu, S. (2019). Helping SMEs internationalise through trade facilitation. OECD Trade Policy Papers, No. 229. Paris: OECD Publishing.

Lusk, J. L. (2018). Separating myth from reality: an analysis of socially acceptable credence attributes. *Annual Review of Resource Economics* 10: 65–82.

Lusk and Polzin (2022). Consumer Food Insights: January 2022. Center for Food Demand Analysis and Sustainability (CFDAS), Purdue University. https://ag.purdue.edu/nextmoves/wpcontent/uploads/2022/02/Survey-Report-Jan2022.pdf. Accessed 20 January 2023.

Marquis, C. and Toffel, M. W. (2012). When do firms greenwash? Corporate visibility, civil society scrutiny, and environmental disclosure. Harvard Business School Working Paper 11-115

McAusland, C. and Najjar, N. (2015). Carbon footprint taxes. *Environ Resource Econ* 61:37–70.

McConkey, B., Haugen-Kozyra, K., Alcock, J., Maynes, T. and Vinke, C. (2019). Global assessment of beef emissions quantification standards and tools. Global Roundtable for Sustainable Beef (GRSB) Phase I Report, available at https://wa.grsbeef.org/resources/Documents/GHG/External%20GRSB%20Phase%201%20Report%202019%2006%2020.pdf. Accessed 11 April 2023.

McFadden, J. *et al.* (2022). The Digitalisation of Agriculture: A Literature Review and Emerging Policy Issues. OECD Food, Agriculture and Fisheries Papers, No. 176. Paris: OECD Publishing.

Meemken, E. M., Barrett, C. B., Michelson, H. C., Qaim, M., Reardon, T. and Sellare, J. (2021). Sustainability standards in global agrifood supply chains. *Nature Food* 2: 758–765.

Meemken, E. M., Qaim, M. (2018). Organic agriculture, food security, and the environment. *Annual Review of Resource Economics* 10: 39–63.

Minten, B., Randrianarison, L. and Swinnen, J. F. (2009). Global retail chains and poor farmers: evidence from Madagascar. *World Development* 37: 1728–1741.

Moltesen, A., Bonou, A., Wangel, A., Bozhilova-Kisheva, K. P. (2018) Social life cycle assessment: An introduction. In: M. Z. Hauschild, R. K. Rosenbaum and S. Olsen (eds), *Life Cycle Assessment: Theory and Practice*. Cham: Springer International, 401–422.

Morgan, S. (2022). Sweden set to be world's first country to target consumption-based emission cuts. Climate Change News. https://www.climatechangenews.com/2022/04/08/sweden-set-to-be-worlds-first-country-to-target-consumption-based-emission-cuts/. Accessed 23 January 2023.

NMPF (2020). FARM Environmental Stewardship Version 2.0 Updates. National Milk Producers Federation. https://nationaldairyfarm.com/wp-content/uploads/2020/02/FARM-ES-Version-2-Fact-Sheet.pdf. Accessed 19 January 2023.

Noels, J. and Jachnik, R. (2022). Assessing the Climate Consistency of Finance: Taking Stock of Methodologies and Their Links to Climate Mitigation Policy Objectives. OECD Environment Working Papers, No. 200. Paris: OECD Publishing.

Norton Rose Fulbright (2022). 10 things to know about the EU Corporate Sustainability Due Diligence proposal. https://www.regulationtomorrow.com/eu/10-things-to-know-about-the-eu-corporate-sustainability-due-diligence-proposal/. Accessed 23 January 2023.

Novy, D. and Taylor, A. M. (2020). Trade and Uncertainty. *The Review of Economics and Statistics* 102: 749–765.

OECD (2019). Enhancing Climate Change Mitigation through Agriculture. Paris: OECD Publishing

OECD. (2022a). *Agricultural Policy Monitoring and Evaluation 2022: Reforming Agricultural Policies for Climate Change Mitigation*. Paris: OECD Publishing.

OECD. (2022b). *Making Agri-Environmental Payments More Cost Effective*. Paris: OECD Publishing.

Pendrill, F., Persson, U. M., Godar, J., Kastner, T., Moran, D., Schmidt, S. and Wood, R. (2019). Agricultural and forestry trade drives large share of tropical deforestation emissions. *Global Environmental Change* 56: 1–10.

Poore, J. and Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science* 360: 987–992.

Poppe, K., Vrolijk, H. and Bosloper, I. (2023). Integration of farm financial accounting and farm management information systems for better sustainability reporting. *Electronics* 12: 1485.

Potter, C., Pechey, R., Clark, M., Frie, K., Bateman, P. A., Cook, B. … Jebb, S. A. (2022). Effects of environmental impact labels on the sustainability of food purchases: two randomised controlled trials in an experimental online supermarket. *PLoS One* 17: e0272800.

Potter, C., Pechey, R., Cook, B., Bateman, P., Stewart, C., Frie, K. … Jebb, S. A. (2023). Effects of environmental impact and nutrition labelling on food purchasing: an experimental online supermarket study. *Appetite* 180: 106312.

PwC (2019). Return on experience is a metric businesses can't ignore: 2019 Canadian Consumer Insights Survey. https://www.retailcouncil.org/wpcontent/uploads/2019/06/pwccanada-2019-canadian-consumer-insights-p567530.pdf. Accessed 20 January 2023.

Rajagopal, D. (2014). Consequential life cycle assessment of policy vulnerability to price effects. *Journal of Industrial Ecology* 18: 164–175.

Rajagopal, D., Vanderghem, C. and MacLean, H. (2017). Life cycle assessment for economists. *Annual Review of Resource Economics* 9: 361–381.

Roberto, C. A., Ng, S. W., Ganderats-Fuentes, M., Hammond, D., Barquera, S., Jauregui, A. and Taillie, L. S. (2021). The influence of front-of-package nutrition labeling on consumer behavior and product reformulation. *Annual Review of Nutrition* 41: 529–550.

Rosenbaum, R. K., Hauschild, M. Z., Boulay, A. M., Fantke, P., Laurent, A., Núñez, M. and Vieira, M. (2018). Life cycle impact assessment. In: M. Z. Hauschild, R. K. Rosenbaum and S. Olsen (eds), *Life Cycle Assessment*. Cham: Springer, 167–270.

Rousset, S. *et al.* (2015). Voluntary environmental and organic standards in agriculture: Policy implications. OECD Food, Agriculture and Fisheries Papers, No. 86. Paris: OECD Publishing.

Sandström, V., Valin, H., Krisztin, T., Havlík, P., Herrero, M. and Kastner, T. (2018). The role of trade in the greenhouse gas footprints of EU diets. *Global Food Security* 19: 48–55.

SEC (2022). SEC proposes rules to enhance and standardize climate-related disclosures for investors. U.S. Securities and Exchange Commission. https://www.sec.gov/news/press-release/2022-46. Accessed 5 January 2023.

Sellare, J., Börner, J., Brugger, F., Garrett, R., Günther, I., Meemken, E. M., Pelli, E. M., Steinhübel, L. and Wuepper, D. (2022). Six research priorities to support corporate due-diligence policies. *Nature* 606: 861–863.

Seufert, V., Ramankutty, N. (2017) Many shades of gray—The context-dependent performance of organic agriculture *Science advances* 3(3): e1602638.

Soler, L. G., Aggeri, F., Dourmad, J. Y., Hélias, A., Julia, C., Nabec, L., Pellerin, S., Ruffieux, B., Trystram, G. and van der Werf, H. (2021) L'Affichage Environnemental des Produits Alimentaires: Rapport du Conseil Scientifique. https://expertises.ademe.fr/sites/default/files/assets/documents/affichage-environnemental-produits-alimentaires-rapport-final-conseil-scientifique.pdf. Accessed 11 April 2023.

Stubbs, M., Hoover, K. and Ramseur, J. L. (2021). Agriculture and forestry offsets in carbon markets: background and selected issues. Congressional Research Service, R46956. https://crsreports.congress.gov/product/pdf/R/R46956. Accessed 7 April 2023.

Swinnen, J. F. ed. (2007). *Global Supply Chains, Standards and the Poor: How the Globalization of Food Systems and Standards Affects Rural Development and Poverty*. Wallingford, UK: Cabi.

Swinnen, J., Deconinck, K., Vandemoortele, T. and Vandeplas, A. (2015). *Quality Standards, Value Chains, and International Development: Economic and Political Theory*. New York: Cambridge University Press.

Swinnen, J. F. M. and Vandeplas, A. (2010). Market power and rents in global supply chains. *Agricultural Economics* 41: 109–120.

Taufique, K. M. R., Nielsen, K. S., Dietz, T. *et al.* (2022). Revisiting the promise of carbon labelling. *Nature Climate Change* 12:132–140.

Thoma, G., Popp, J., Shonnard, D., Nutter, D., Matlock, M., Ulrich, R., Kellogg, W., Kim, D. S., Neiderman, Z., Kemper, N. and Adom, F. (2013). Regional analysis of greenhouse gas emissions from USA dairy farms: A cradle to farm-gate assessment of the American dairy industry circa 2008. *International Dairy Journal* 31: S29–S40.

Traldi, R. (2021). Progress and pitfalls: a systematic review of the evidence for agricultural sustainability standards. *Ecological Indicators* 125: 107490.

Trase (2020). The state of forest-risk supply chains: Trase Yearbook 2020 – Executive Summary. http://resources.trase.earth/documents/Trase_Yearbook_Executive_Summary_2_July_2020.pdf. Accessed 16 June 2023.

Verweij-Novikova, I., Broekema, R. and Boone, K. (2022). Product environmental footprint: overview of EU and national public and private initiatives in agro-food. Wageningen University and Research. https://library.wur.nl/WebQuery/edepot/577700. Accessed 7 April 2023.

Waka Eke Noa, H. (2022). Greenhouse gas emissions calculation tools. https://hewakaekenoa.nz/tools-and-calculators/. Accessed 19 January 2023).

WBCSD (2022). Partnership for Carbon Transparency (PACT) sets foundations for standardized emissions data exchange: new tech specifications will enable data exchange across different technology solutions. World Business Council for Sustainable Development. https://www.wbcsd.org/Programs/Climate-and-Energy/Climate/SOS-1.5/News/Partnership-for-Carbon-Transparency-PACT-sets-foundations-for-standardized-emissions-data-exchange. Accessed 6 January 2023.

WBCSD (2023). Pathfinder framework: guidance for the accounting and exchange of product life cycle emissions, version 2.0. Partnership for Carbon Transparency (PACT). World Business Council for Sustainable Development (WBCSD).

White, K., Hardisty, D. J. and Habib, R. (2019). The elusive green consumer. Harvard Business Review. https://hbr.org/2019/07/the-elusive-green-consumer. Accessed 5 January 2023.

World Economic Forum (2022). Supply Chain Sustainability Policies: State of Play. White Paper. https://www3.weforum.org/docs/WEF_Supply_Chain_Sustainability_Policies_2022.pdf. Accessed 13 January 2023.

WTO (2021)."What yardstick for net-zero? How WTO TBT disciplines can contribute to effective policies on carbon emission standards and climate change mitigation. Trade and Climate Change Information Brief n° 6. https://www.wto.org/english/news_e/news21_e/clim_03nov21-6_e.pdf. Accessed 6 January 2023.

Zu Ermgassen, E. K., Ayre, B., Godar, J., Lima, M. G. B., Bauch, S., Garrett, R., Green, J., Lathuillière, M. J., Löfgren, P., MacFarquhar, C. and Meyfroidt, P. (2020a). Using supply chain data to monitor zero deforestation commitments: an assessment of progress in the Brazilian soy sector. *Environmental Research Letters* 15: 035003.

Zu Ermgassen, E. K., Godar, J., Lathuillière, M. J., Löfgren, P., Gardner, T., Vasconcelos, A. and Meyfroidt, P. (2020b). The origin, supply chain, and deforestation risk of Brazil's beef exports. *Proceedings of the National Academy of Sciences* 117: 31770–31779.