Background Note for the

GLOBAL FORUM ON AGRICULTURE

CARBON FOOTPRINTS FOR FOOD SYSTEMS

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This background note explains recent developments around the measurement and communication of carbon footprints (and other environmental impacts) in food systems, and discusses drivers and potential impacts.

1 Introduction

Food systems are facing pressures to transform. In the coming decades, it is likely that firms will increasingly need to report detailed, quantitative information on carbon footprints and other 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 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 private initiatives, such as environmental impact labelling on food products, green public procurement, or carbon pricing.[1]

Although carbon footprints and other 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 estimation or modelling of emissions will become more accurate over time.

[1] In line with common practice, throughout this paper the term "carbon" refers to all greenhouse gases, not only CO_2.

In contrast with 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 carbon footprints and other 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, presenting a confusing landscape of organizations, approaches, proposals, and methodologies competing for attention. It will have far-reaching consequences along the entire food supply chain, and may lead to a reorientation of global trade flows and a reorganization of global 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 environmental sustainability of food production will only grow.

This paper discusses the trend towards carbon footprint reporting in food systems, its drivers, and possible impacts and pitfalls, identifying many open research and policy questions along the way.[2]

The remainder of this paper is organized as follows. Section 2 outlines three main levels at which carbon footprints can be reported – product, project, and firm. Section 3 identifies the long-term drivers underpinning the trend towards carbon footprint reporting. Section 4 then discusses possible impacts in terms of environmental outcomes as well as in terms of effects on producers, supply chain organization, and trade flows. Section 5 outlines possible pitfalls. These include conceptual, technical, and implementation issues. The concluding section reflects on implications for research and policy.

[2] Carbon footprints are the most advanced example of environmental impact reporting, but similar approaches can be used for other environmental impacts, although methodologies differ in their maturity and robustness (Deconinck and Toyama, 2022).

2 Three levels of reporting

Reporting of carbon footprints and other environmental impacts related to food systems can take place at several levels. We here distinguish three levels: product, project, and firm.[3]

Product level

At the product level, carbon footprints and other environmental impacts can be reported using Life-Cycle Assessment (LCA) (Hauschild et al., 2018; Cucurachi et al., 2019). Findings can be used to guide business decision making, to inform policy choices, or to provide information to consumers (Rajagopal et al., 2017). Several carbon footprint labels exist, such as the Carbon Trust's product carbon footprint label.[4] Other initiatives are developing labels capturing multi-dimensional environmental impacts. The European Commission has been developing its Product Environmental Footprint (PEF) methodology to provide a uniform approach to environmental impact claims in the EU (European Commission, 2021). In the UK, the Foundation Earth initiative issues environmental front-of-pack labels as well as detailed online factsheets for food products, based on LCA and covering several environmental impacts besides carbon footprints. The initiative is supported by major retailers (e.g. Aldi, Lidl, Tesco, Sainsbury's) and other supply chain actors (e.g. Danone, Unilever, Nestlé, PepsiCo).[5] In France, similar schemes (e.g. Eco-score, Planetscore) were piloted in preparation of public regulations on environmental impact labels for food products (Gouvernement de la République Française, 2022).

Project level

Carbon reporting can also take place at the project level – for example, by measuring or estimating the amount of GHG emissions sequestered in a specific soil carbon sequestration project. In principle, such estimates could then be used to generate credits or offsets. In France, the *Label Bas Carbone* is a voluntary government-backed scheme to assess emissions reductions from projects. Private-sector actors can fund these projects and in turn receive non-tradable offsets.[6] The Australian Emission Reduction Fund can similarly award Carbon Credit Units to projects which 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 et al., 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 so-called 'compliance markets' (those that are compliant with national and international law), such as the EU Emissions Trading Scheme or the Clean Development

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[3] Reporting can also take place at country level (e.g. the annual reporting under the Kyoto Protocol) or, for financial institutions, at the level of an investment portfolio.

[4] See https://www.carbontrust.com/what-we-do/assurance-and-labelling/product-carbon-footprint-label (accessed 15 February 2023).

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

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

Mechanism. Instead, credits from soil carbon projects tend to be traded in voluntary markets, at lower prices (Henderson et al., 2022; Henderson et al., 2020).[7]

Firm level

Firms are increasingly reporting on the GHG emissions and other environmental impacts associated with their activities – and in many cases also on 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% 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% relative to 2021 (CDP, 2022). This includes many agri-food firms. In 2021 (the latest year for which detailed data is 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). Firms are facing increasing pressures to report not only emissions from their own operations (referred to as 'Scope 1' in the terminology of 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 below, several jurisdictions have been strengthening the requirements for carbon footprint reporting by firms. In addition to mandatory disclosure, there is also pressure on companies (by civil society, but also investors) to provide greater voluntary disclosure of environmental impacts. Farmers are also increasingly asked to report carbon footprints and other 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.[8]

These levels of reporting do not operate in isolation, as similar methods and datasets may be used for each. Moreover, organizations 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, product-level carbon footprint data received from suppliers can be used to calculate Scope 3 firm-level emissions (WBCSD, 2023). 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.

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

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

3 Drivers

As the examples in the previous section show, reporting of carbon footprints and other environmental impacts is already occurring in the agri-food sector, even if many initiatives are still at an early stage, and many are voluntary. Yet, reporting 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.

The demand for information on carbon footprints and other environmental impacts

On the demand side, citizens frequently indicate in surveys that environmental sustainability is important to them (Arreza, 2020; Capterra, 2021; BEUC, 2020; EY, 2021; Fabric, 2021; Lusk and Polzin, 2022; PwC, 2019). So far, however, there remains a major gap between intentions and behaviour (Lusk, 2018; White et al., 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% of food sales in high-income countries despite decades of development and promotion (Deconinck and Hobeika, 2022).[9] 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).

In response, retailers and other supply chain actors are increasingly working together to measure, communicate, and improve various sustainability criteria. 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% or more in France and Italy (Carbon Trust, 2020).

Investors are also demanding greater information. This may partly reflect individual 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 consciousness among consumers, could impose financial costs and reputational damage on firms with a poor environmental performance. Investors 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, J.P. Morgan, or Credit Suisse, 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 antibiotics use, working conditions, and

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

animal welfare. As the organization 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 emissions 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, proposed new rules by the Securities and Exchange Commission would similarly require firms with securities traded in U.S. 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 a significant share of agri-food emissions in the EU and the U.S. would be affected by these rules. Government procurement is another driver. In November 2022, the U.S. 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. The European Commission is preparing a proposal on green claims, which would require firms to substantiate claims about the environmental impact of their products using standardized methods (European Commission, 2022).

Finally, civil society organizations have been an important voice demanding greater transparency and accountability, and activities by these organizations underpin many of the other demand drivers – e.g. by publicizing negative environmental impacts of major actors in food systems, or by lobbying governments for stricter regulations.

The supply of information on carbon footprints and other environmental impacts

In parallel with these demand-side trends, several developments are making it easier to supply the requested information.

A first factor is the development of standards. Both GHG Protocol and ISO have standards for carbon footprint calculations at the product, project, and firm level.[11] At the EU level, the Product Environmental Footprint and Organization Environmental Footprint methodologies have been developed by the European Commission's Joint Research Centre to provide a harmonized approach (European Commission, 2021). These generic standards are often complemented by country- and sector-specific standards (WTO 2021; WBCSD, 2023). For agri-food products, for example, GHG Protocol launched its Agriculture Guidance in 2014 and is currently developing its Land Sectors and Removals Guidance, which is expected to be

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

[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 (e.g. the Land Use, Land-Use Change, and Forestry (LULUCF) Guidance). Firm- or organization-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 level (product, project, and firm), while standards for Life Cycle Assessment (ISO 14040:2006 and ISO 14044:2006) have provided an overall conceptual framework for most other approaches.

finalized in 2023. Accounting standards are also evolving to provide harmonized guidance on sustainability reporting. In 2021, the IFRS Foundation, which sets global accounting standards, established the International Sustainability Standards Board (ISSB) to set standards for sustainability disclosures.[12] In October 2022, the ISSB announced that its standards will require Scope 3 emissions reporting.[13] These standards 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 (FLAG) Guidance, assisting companies in setting reduction targets covering all land-related emissions.[14] In November 2022, ISO released its Net Zero Guidelines, which attempt to offer a common understanding of 'net zero' and related concepts.[15]

A second factor is the growing availability of calculation tools to estimate carbon footprints and other environmental impacts. Reporting standards typically do not prescribe a specific calculation methodology. For example, 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, 2011). 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.[16] 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 FARM Environmental Stewardship tool developed by the National Milk Producers Federation in the United States, based on peer-reviewed research (Asselin-Balençon et al., 2013; Thoma et al., 2013). Another example is COMET-Farm, developed by the U.S. Department of Agriculture.[17] 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 (He Waka Eke Noa, 2022). The availability of such calculators 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 (Bord 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).

A third and related driver is the growing availability of evidence and data which 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

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

[13] 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).

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

[15] See https://www.iso.org/netzero (accessed 13 January 2023).

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

[17] See https://www.comet-farm.com/ (accessed 27 January 2023).

necessary to quantify the amounts of fertilizers 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 (GLAD) currently indexes more than 80 000 LCA datasets. Another example is Hestia (www.hestia.earth), a joint initiative of Oxford University, WWF, and the Login5 Foundation which provides an open-access platform that stores standardized 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) synthesized findings from 570 studies covering nearly 40 000 regional- or farm-level assessments in 119 countries to derive estimates of environmental impacts of agri-food commodities, while Gephart et al (2021) similarly synthesized findings from 61 studies on fish and seafood.[18] In turn, Clark et al. (2022) used these results to estimate environmental impacts of 57 000 food products as found at retail level. In France, the Agribalyse database (created by ADEME and INRAE) contains harmonized LCA information on nearly 2 500 food products, and is used as the reference dataset for the development of environmental impact labels.[19]

A fourth factor is the emergence of platforms to enable the sharing of carbon footprint information. As noted earlier, the number of firms disclosing their GHG emissions 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 life-cycle assessments. The Partnership for Carbon Transparency, an initiative of the World Business Council for Sustainable Development, has released technical specifications for the standardized exchange of carbon emissions data; these specifications create interoperability between different emissions accounting systems (WBCSD, 2022; 2023).

A fifth factor is the development of new technological solutions for directly measuring carbon footprints and other 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.[20] 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, reporting on carbon footprints and other environmental impacts 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.

Broader trends

In addition to these demand- and supply-side factors, there are some broader trends which facilitate the growth of carbon footprint reporting.

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

[18] A much smaller number of life-cycle assessments looks at meat protein alternatives; see Frezal et al. (2022) for a discussion.

[19] See https://agribalyse.ademe.fr/ (accessed 30 January 2023).

[20] See https://climatetrace.org/ (accessed 30 January 2023).

a ‘duty of care’ law in place since 2017, while the German Supply Chain Due Diligence Act came into effect on 1st January 2023. In the Netherlands, a Bill for Responsible and Sustainable International Business Conduct was introduced in Parliament in November 2022. The United Kingdom’s Environment Act 2021 also contains due diligence requirements for ‘forest risk commodities’. The OECD Due Diligence Guidance for Responsible Business Conduct (OECD, 2018), together with related sector-specific guidance such as that for agricultural supply chains (OECD/FAO, 2016), provides an authoritative government-backed framework for due diligence, taking an explicit supply chain lens. 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 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, health inspections) and algorithms to reconstruct sub-national supply chains of agricultural commodities linked to deforestation. In turn, this information has been used to develop more granular life-cycle assessments (e.g. Escobar et al., 2020), to map deforestation risks of Brazilian beef production (Zu Ermgassen et al., 2020a), to study the impact of international trade on biodiversity loss (Green et al., 2019), or to 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 above, retailers and investors are increasingly vocal about the need for greater transparency on carbon footprints and other environmental impacts of food, and, increasingly, firms are signing up to ambitious GHG mitigation targets set by the Science-Based Targets initiative. 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% between 2015 and 2030), but also leading retailers such as Tesco (Scope 3 target of -17% by 2030 relative to 2015), Carrefour (-29% by 2030 relative to 2019) and Ahold Delhaize (-37% 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.[21] Such commitments translate into more stringent requirements on suppliers (and hence, ultimately, farmers), in a process reminiscent of the rise of private standards (Beghin et al., 2015; Fulponi, 2006). Yet, the rise of private initiatives does not occur in a vacuum. As noted earlier, government policy is often directly mandating greater reporting of carbon footprints and other environmental impacts. 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 information grows (e.g. through improved datasets and technological solutions), it may become easier for governments to introduce more ambitious

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

mandatory disclosure rules.[22] This interplay between private and public actors is reminiscent of the “green spiral” identified by Kelsey (2021) in the context of international ozone negotiations.

[22] For example, the proposed U.S. 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 (TCFD) standard, CDP, and the Science Based Targets Initiative (SBTi).

4 Impacts

Greater transparency requirements regarding carbon footprints and other 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.

If implemented using reliable and comparable methodologies, the move towards carbon footprint reporting could be a catalyst for more sustainable consumption and production choices. Product-level information can inform consumer choices (e.g., through labels), but can also be used as building block for other policy interventions, e.g., green public procurement or fiscal measures. Moreover, detailed LCAs can also be used by companies to identify hotspots in their production processes and supply chains, informing actions to improve environmental sustainability (including targeted R&D investment). Carbon footprint reporting at the firm level can be used to benchmark companies against their peers, and to monitor firms' commitments to climate mitigation targets, creating greater accountability.

To understand the potential impact of better information, consider the benchmark of a Pigouvian carbon tax under perfect information. Such a tax would achieve optimal mitigation through several 'margins of adjustment'. 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 incentivize all actors along the food supply chain to change techniques to lower their emissions, including through 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% 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% of soy-producing municipalities, while in Indonesia, 6% 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 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, OECD 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 (Gruère et al., forthcoming; Henderson and Verma, 2021). 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). 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. 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 implementation pitfalls which need to be avoided.

Conceptually, assessments of carbon footprints and other environmental impacts involve a large number of decisions, for example on which stages of the life cycle are considered in scope, how 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). When several environmental dimensions are covered (as is the case in the EU Product Environmental Footprint, 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 judgments (Rosenbaum et al., 2018). An 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 carbon footprints and other 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 measurements 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. In the European Union, for example, fewer than 18 000 industrial installations report their emissions under the Emissions Trading Scheme – yet there are more than nine million farms. Even if detailed quantification efforts were restricted to large farms with 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.[23] Moreover, food systems are global, and a significant share of GHG emissions and other 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 carbon footprints and other 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.

[23] 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).

There are also some practical workarounds which could provide reasonable estimates at lower transaction costs. One possibility is to develop a set of 'rebuttable' default values (McAusland and Najjar, 2015; Heine et al., 2021). A standard database could be used as the reference for carbon footprints and other environmental impacts of a product, unless firms provide their own verified assessment. Especially where fiscal incentives are linked to product-level environmental impacts, this could provide an incentive for firms to invest in assessments, leading to a greater evidence base over time. This approach could strike a balance between the need for fine-grained data (to incentivize change on all three margins of adjustment discussed above) and the objective of keeping transaction costs low.

However, greater difficulties may arise on the implementation side. A major risk is that the trend towards carbon footprint 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 (ESG) 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 and barriers to trade.

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 harmonized standards for calculating and reporting carbon footprints and other environmental impacts. This would reduce transaction costs and would also remove a potential source of trade frictions, as the Technical Barriers to Trade (TBT) Agreement considers that regulations based on international standards are *a priori* not unnecessarily trade restricting (WTO, 2021). As noted above, several standards for measuring carbon footprints currently exist, including the GHG Protocol and ISO standards. But frictions are perhaps 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 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 U.S. 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.

As a result, firms may be asked to demonstrate the reliability of their carbon footprint estimates, for instance through 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 harmonization of verification approaches through international standards and encourage countries to accept 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 (SDoC), among other approaches (WTO, 2021). 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 small- and medium-sized enterprises (Lopez González and Sorescu, 2019).

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).

Since uncertainty imposes costs on firms and reduces trade increased effort to address these pitfalls is essential (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 harmonization 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 specialization, 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 et al., 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 food system transformation may now have started, characterized by reporting of carbon footprints and other environmental impacts.

Such reporting can take place at the level of a product, project, or firm. While many initiatives are currently in an early stage, their development and uptake are accelerating in response to growing demand for this information, and a growing supply of standards, methodologies, datasets, and technologies to deliver it. Accounting and reporting standards play a central role in these dynamics.

Under ideal conditions, the rise of carbon footprint and other 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 reorganization of supply chains, with possibly adverse consequences on small-scale producers in low- and middle-income countries. In addition, there are several pitfalls which need to be avoided in setting up a reliable system of reporting. These include conceptual problems (e.g., which stages to include, how to account for by-products), technical questions (e.g., how to measure or estimate these impacts, given the large number of producers), and implementation questions (e.g. how to avoid a fragmentation of approaches leading to high transaction costs).

In addition to funding research on these questions, policy makers should 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 policy makers encounter a potential fragmentation of private-sector approaches, there might be scope to encourage harmonization or to introduce a public standard. While most attention currently goes to carbon footprints, policy makers 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 policy makers 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 organizations (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, policy makers should also consider how new initiatives will affect poor, small-scale producers in low- and middle-income countries, and should explore what can be done to minimize 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.

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