Transparency and Accountability on the Path to Net-Zero

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Abstract

Numerous multinational firms have recently pledged to reduce their greenhouse gas emissions to a net-zero position by the year 2050. These pledges currently lack a unified measurement and reporting structure, leaving the public unsure about the extent of the corporate commitments. Here, we propose a Time-Consistent Corporate Carbon Reporting (TCCR) standard that entails an initial forecast of a firm's future carbon emissions trajectory, periodic revisions of the earlier forecasts, and updates on emissions reductions actually achieved at different points in time. The TCCR standard is applicable to alternative carbon footprint metrics, including a company's direct emissions, carbon emissions in goods sold, or the carbon footprint assessed for individual sales products.

JEL classification: M41-Accounting, Q53-AirPollution, Q54- Climate

1. Introduction

As governments around the world reaffirm their commitments to reduce carbon emissions at national levels, numerous corporations have recently issued their own carbon reduction pledges. According to a recent survey, more than two-thirds of the Fortune 500 firms have by now articulated "net zero by 2050" goals with regard to their greenhouse gas emissions.[1] Globally, a survey of the largest 2,000 multi-national firms reported that more than 20% of respondents have issued such pledges.[2] With pressure from institutional investors, customers and employees building, net-zero pledges are increasingly becoming a "must" for companies seeking to convey their commitment to rapid decarbonization.

Two issues commonly raised in connection with recent carbon reduction pledges are the length of the pledge horizon and a lack of comparability in what, precisely, is being pledged. Analysts and observers have long pointed out that a mere pledge that comes due in the year 2050 is generally beyond the accountability horizon of current executives. Some studies argue that net-zero targets would become more credible if they include milestones, an implementation plan, and a statement about longer-term intent for either maintaining net zero or going net negative.[3] Several recent studies point to considerable variation in the measurement of corporate carbon footprints and in reporting progress towards the target of full decarbonization.[4,5,6,7,6,8] More broadly, earlier literature has expressed concern over greenwashing in corporate commitments, pointing to "decoupling" of commitments and concrete actions, and a general lack of corporate accountability.[9,10,11,12]

Our objective in this perspective article is to describe an integrated carbon emissions reporting framework intended to strengthen the transparency and credibility of existing net-zero pledges. We refer to this framework as *Time-Consistent Corporate Carbon Reporting* (TCCR). Firms adhering to the TCCR framework would commit to disclose the following information: (i) the annual reporting of a specific corporate carbon footprint metric, (ii) an initial forecast of the future trajectory of this metric up to the year 2050, and (iii) periodic revisions of the forecast for the remaining years up to 2050.

The concept underlying the TCCR standard is known from managerial accounting textbooks as "variance analysis". Accordingly, performance targets, which may have been self-selected by a departmental manager or negotiated with superiors, are periodically revised. Further, performance of the organizational unit is assessed by the time-series of discrepancies (variances) that compare target levels to actual results delivered in each period. The TCCR standard adheres to the general principles for effective disclosure as promulgated by the Taskforce for Climate related Financial Disclosure (TCFD) recommendations.[13] Accordingly, such disclosures should be unambiguous, consistent over time, comparable among companies within a sector, industry, or portfolio, and provided on a timely basis. Certain features of our reporting standard are also aligned with the carbon pledge requirements described within the recent SBTi Net Zero Standard Framework[14] and the UN Environment Program Finance Initiative Guidelines for Climate Target Setting.[15]

The TCCR standard is based on at least one carbon footprint metric that is measured consistently over time. In accordance with the Greenhouse Gas (GHG) Protocol, many companies report a flow measure of their carbon footprint that includes Scope 1, Scope 2 and select categories of their Scope 3 emissions, e.g., employee travel and commuting. One recent innovation in this context is that some multinational companies have adopted internal accounting systems in order to determine the carbon footprint of their sales products.[16,17] In accordance with the general E-liability framework[18], these companies seek to measure the cradle-to-gate carbon footprint of their products in a sequential manner along their upstream supply chains. By relying on primary emissions data at each link of the supply chain, companies gain a reliable measure of the "Upstream Scope 3" emissions embodied in their products. When embedded in the dynamic reporting framework of the TCCR standard, this metric will provide added transparency to a firm's net-zero pledge.

We do not view the TCCR standard as an effective substitute for regulatory policies that could drive the rapid decarbonization process envisioned in the 2015 Paris Climate Agreement. Neither do we expect the TCCR framework to become a mandatory corporate reporting

requirement. Financial regulators have traditionally confined disclosure mandates to information items pertaining to past transactions, without obliging firms to issue multi-year forecasts of key financial or environmental performance metrics.

We submit, however, that voluntary adoption of the TCCR standard by a subset of the firms that have issued net-zero pledges would already bring added transparency to this movement. Selective adoption of the TCCR standard will enable those firms that set ambitious emission reduction targets, and, in fact, expect to achieve these targets, to separate themselves from others that simply seek to wear the "green mantle". The TCCR standard therefore has the potential to serve as a separation mechanism that will make the net-zero commitments of its adopters more credible and transparent, for both policy makers and the general public.

2. Time-Consistent Corporate Carbon Reporting

Time consistent carbon reporting is based on one or multiple emission metrics measured consistently over time. For any such metric, the unit of measurement is tons of CO_2, with greenhouse gases other than CO_2 appropriately weighted according to the IPCC guidelines. The metric(s) adopted by a particular firm will depend on the scope of emissions for which it considers itself responsible. The default metric for many companies has been their direct (Scope 1) emissions. Some companies have recently adopted carbon footprint metrics that go beyond their direct emissions, as they view themselves at least indirectly responsible for the emissions embodied in the goods and services they provide.

Time-consistent Corporate Carbon Reporting (TCCR) holds firms accountable for their earlier net-zero pledges by requiring periodic updates of the original pledge. In particular, the standard requires firms to issue a series of future emission trajectories that are subsequently compared to actual reductions achieved over time. Figure 1 illustrates the TCCR framework for a hypothetical firm in the year 2035, assuming this firm adopted the framework in 2020.

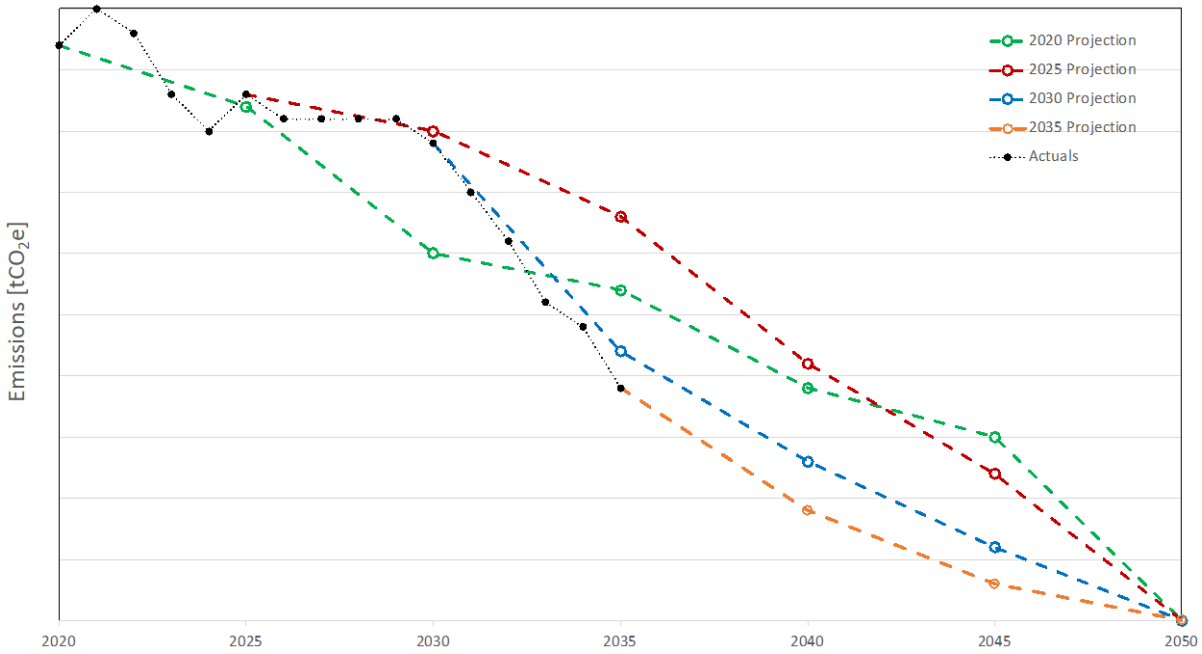

Figure 1: **Time-Consistent Corporate Carbon Reporting**

For the hypothetical scenario in Figure 1, the company issued an initial forecast of its future carbon emissions trajectory in 2020 (green curve). As drawn here, the trajectory implicitly assumes a linear interpolation between the target emission levels at the five-year milestones in the future. In this example, the firm's actual emissions were above the linear interpolation for the years 2020-2025 in all but two years. In 2025, the firm barely missed its interim target. Our illustration further assumes that a revised, less ambitious forecast trajectory (red curve) was issued in 2025. It initiated at the actual emissions level in 2025 and stayed in effect until 2030. When future updated forecast trajectories are "spliced" together with actual results up to a particular point in time, the public obtains an integrated picture of earlier forecasts, forecast revisions and actual results. Importantly, it becomes transparent to what extent the earlier targets and target revisions were temporally consistent with the actual results delivered.

A disclosure regime that includes interim reduction targets at multiple milestones will mitigate the horizon issue that arises when management anticipates in 2022 that by the year 2050 it will no longer be accountable for its initial pledge. Interim targets might be set in accordance with guidelines formulated by the SBTi, for example, which seeks to balance industry-specific

reduction trajectories with the remaining global carbon budget up to the year 2050. However, recent studies have raised concern that some of the corporate carbon reduction pledges issued in the last few years may have been overly optimistic.[19] In contrast, the TCCR framework provides incentives for self-selecting targets that are deemed realistic rather than overly optimistic. Managers will anticipate that the actual emission results achieved in future years are compared to the earlier self-selected targets, and crucially, these performance assessments will be made in the near future. Further, the public will be able to track on an annual basis to what extent actual emissions did meet the milestone targets originally selected, and subsequently revised at different points in the past.[20] The TCCR standard thus provides an integrated performance assessment mechanism similar to that used by firms tracking internally the extent to which actual outcomes have achieved earlier performance targets.

3. Alternative Carbon Footprint Metrics

The Greenhouse Gas Protocol

The Greenhouse Gas (GHG) Protocol has long been the universal standard for companies to measure and report their corporate carbon footprints.[21] Accordingly, a firm's total emissions include direct (Scope 1) and indirect (Scope 2 and 3) emissions. Indirect emissions principally comprise a firm's entire upstream supply chain as well as all emissions associated with the use of the firm's downstream products. To that end, the GHG Protocol identifies 15 different Scope 3 categories as well as minimal boundaries for each category. Scope 2 emissions are a carve-out of the general bucket of indirect emissions, focusing exclusively on emissions associated with electricity and heat acquired from external suppliers.

The enormous data challenge of reliably estimating a company's full Scope 3 emissions is readily illustrated in the context of an automotive company.[22] On the upstream side, the GHG Protocol suggests that the company estimate the carbon emissions associated with the manufacture of the tens of thousands of different components that go into its automobiles. On the downstream product use side, the Scope 3 estimate for a particular year is supposed to include an estimate of the entire stream of future tailpipe emissions generated by driving the

automobiles. This inclusive life-cycle definition leads Toyota to report that 98% of its emissions associated with a vehicle are indeed Scope 3 emissions.[23]

The consumer products conglomerate Unilever assesses its downstream Scope 3 emissions simplistically by leveling a flat 46g of CO_2 charge "per use" on all its products, be they food items or skin care products.[24] Technology firms like Google indicate that they draw narrow boundaries for their Scope 3 emissions by including only employee commuting and travel.[25] Not surprisingly, recent independent analysis suggests that companies in the technology sector underreport their Scope 3 emissions by about half relative to the GHG protocol standards.[26] For a sample of 417 companies, another recent study found that the vast majority disclosed their Scope 1 and 2 emissions, about 20% included some Scope 3 figures, yet did so in a manner that was inconsistent within and across industries.[10] In its 2022 exposure draft on requiring disclosures of climate related risks by publicly listed corporations, the SEC acknowledges the difficulty of reliably reporting Scope 3 emissions.[27] Specifically, the proposal envisions that any Scope 3 disclosures would be protected from legal liability under a "safe harbor" provision.

Direct Net Emissions (DNE)

The measurement and reporting of direct emissions is already mandatory for companies in jurisdictions that have implemented carbon pricing mechanisms, such as the European ETS or California's cap-and-trade program. To implement such pricing mechanisms, the jurisdictions had to specify detailed measurement and verification protocols.[28] Further, while the U.S. does not have a national pricing rule for greenhouse gas emissions, the U.S. Environmental Protection Agency's GHG Reporting Program[29] requires carbon-intensive installations, such as natural gas power plants and cement producing factories, to report their direct emissions.

Most firms that have issued net-zero pledges calculate their net carbon footprint metric by subtracting carbon offsets from gross emissions. Returning to the example of Google, the firm claims to be already carbon neutral despite the significant Scope 2 emissions associated with the grid-based electricity consumed by its data centers. Google bases this neutrality claim on a

carbon accounting construct that effectively swaps the "clean electrons" delivered to the grid by Google's renewable energy facilities for the grey electrons actually consumed at the company's grid-connected operational centers. In calculating its net carbon footprint, the firm thus subtracts these offsets from its gross Scope 2 emissions. The accounting logic underlying these so-called avoidance offsets (in contrast to removal offsets discussed below) is that because the company supplied clean energy to the grid in some location, other energy consumers purchased less of the carbon-intensive energy generated in those locations. Recognizing the tenuous nature of such avoidance offsets, Google has increasingly moved to pursue decarbonized electricity for its operations on a gross basis.[30]

Aside from carbon-free energy supplied to the market, avoidance offsets can originate, for example, from a forest that would have been logged, but instead was conserved. The conceptual construct of trading avoidance offsets is that the buyer deducts as many tons of CO_2 from its gross emissions count as were supposedly not emitted by the seller due to the buyer's intervention and payment. In general, avoidance offsets are based on a counterfactual claim, thereby leaving unresolved the question of "additionality" of the mitigating action.[31,32,33] In 2021, the transaction prices for carbon offsets in the voluntary carbon markets varied anywhere from $2 - $800 per ton of CO_2, with the median price near $5 per ton. The enormous size of this price range suggests significant underlying quality variances. Nonetheless, the Taskforce on Scaling Voluntary Carbon Markets (TSVCM) reports that 90 percent of offsets adhere to some verification through certification bodies, such as Verified Carbon Standard or American Carbon Registry. As of today, there does not appear to be a bright-line standard for what constitutes a "high-quality" carbon avoidance offset.

In contrast to avoidance offsets, removal offsets emerge when the firm, or a contractor acting on behalf of the firm, directly removes carbon dioxide from the atmosphere. Removal offsets therefore constitute direct emission reductions, in contrast to the indirect reductions recognized with avoidance offsets when another party allegedly chose not emit CO_2. One removal technology that has gained prominence in recent years is direct air capture, where CO_2 is removed from the ambient air and thereafter sequestered in geological sites for hundreds of

years. Nature-based carbon sinks, like forests,[34] soils,[35] or oceans[36] present other carbon removal opportunities.

We adopt the position taken by the SBTI[37], advocating that only removal offsets, but not avoidance offsets, be included in the firm's direct net emissions (DNE) footprint metric. Companies will achieve greater transparency on their decarbonization pledges by disaggregating their DNE figures into gross direct emissions and removal offsets. These two separate components of the DNE metric could be applied to both future targets and actual results achieved.

Since removal offsets may vary considerably in their expected duration[38,39,40,41], any recognized removal offsets should be supplemented with information describing the duration profile of the entire portfolio of a firm's removal acquisitions.[42,43] Firms could consider the possibility of recognizing removal activities with shorter duration at a discount value. In addition to new ratings agencies emerging in this domain, the Integrity Council on Voluntary Carbon Markets seeks to formulate minimum quality standards for removal offsets, particularly with regard to the lingering issue of duration.[44,45]

An appealing fundamental property of the DNE metric is that when added up across all economic entities, that is, firms, households, and other carbon emitting entities, the aggregate DNE in any given year yields the net addition of CO_2 equivalents to the atmosphere in that year. This additivity property is important from a global climate policy perspective. Consider our hypothetical scenario in Section 2 above, where the firm has delivered up to the year 2035 the actual results shown in Figure 1. In accordance with the TCCR standard, this firm issues in 2035 a new net-zero pledge, represented by the three dashed lines in Figure 2, leading up to the year 2050.

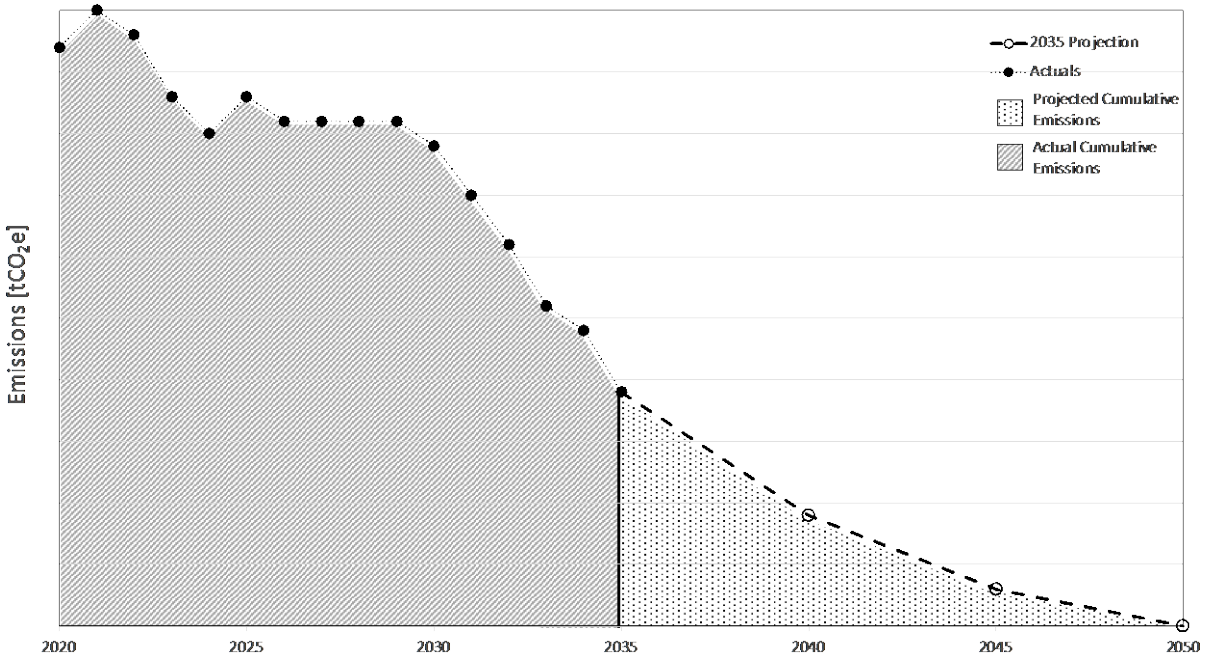

Figure 2: **Corporate DNE Pledges and Global Carbon Budgets**

The dotted area under the dashed lines for the years 2035-2050 represents a forecast of the direct net emissions by the firm in question. By adding up these shaded areas vertically across all firms that have issued net-zero pledges, one obtains a lower bound on the remaining total net emissions that the entire corporate sector projects up to 2050. The informativeness of this lower bound increases as more global firms adopt the TCCR standard. In order to meet a given 1.x^{o} global warming goal (with 1.x^{o} between 1.5^{o} and 2.0^{o}), the lower bound on total emissions would have to be compatible with the remaining carbon budget that climate science assigns the world in 2035 in order to keep global temperature increases below 1.x^{o} Celsius.

Countries around the world provide annual estimates of the direct CO_2 emissions originating within their borders. The preceding argument is therefore also applicable in settings where the entities adopting the TCCR framework are entire countries rather than individual companies. Implemented consistently, the framework could aid countries in negotiations at future COP meetings to reach agreement on their intended nationally determined contributions towards the reductions in global carbon emissions. Specifically, so-called Corresponding Adjustments

defined within Article 6 of the Paris Climate Agreement could be formalized within the TCCR framework.

One widely recognized drawback of the DNE footprint metric is that companies can claim emission reductions simply by "moving the gates", that is, by divesting themselves from carbon intensive activities, such as power generation. Such restructuring activities effectively amount to carbon leakage. Outsourcing carbon intensive activities will be particularly tempting if the divesting company has issued ambitious net zero pledges, while the acquiring company has not, possibly because the acquirer is not a publicly listed company.[46]

Carbon Emissions in Goods Sold (CEGS)

Firms that confine their corporate carbon footprint measure to DNE may do so either because they only consider themselves responsible for their own direct emissions, or because they view the data challenges associated with Scope 3 measurement as effectively prohibiting reliable reporting of those emissions. Recent studies have pointed out that the task of measuring upstream Scope 3 emissions can, at least in principle, be solved in a recursive manner by the firms along a supply chain.[47] The central idea underlying Kaplan and Ramanna's (2021) E-Liability concept is that when a supplier delivers a product or service to its customers, the transaction should be accompanied by a carbon balance (an E-liability) reflecting the emissions that have thus far gone into the product. When the customer subsequently transforms the inputs obtained from suppliers into product outputs, it assigns its own direct net emissions and the emissions embodied in its inputs to its products.

An appealing feature of the E-liability approach is that the recursive assignment of carbon footprints to products can proceed in an informationally decentralized manner, that is, by relying on local knowledge, based on primary data, at each stage.[48] This feature aligns with the general disclosure principles of the Sustainability Accounting Standards Board (SASB), postulating that disclosure items be "actionable" by the firm, that is, these items must be within the operational purview of the reporting entity.[49]

Figure 3 illustrates an emissions assignment rule for an individual facility (plant). The annual direct emissions of CO_2 equivalents at the installation may comprise multiple components, represented here as $(y_1,\ldots,y_m)$. The variable, r, refers to CO_2 removals that the firm has acquired and assigned to the installation in question. Direct net emissions for the year in question therefore are: $DNE = \sum_{i=1}^{m} y_i - r$.

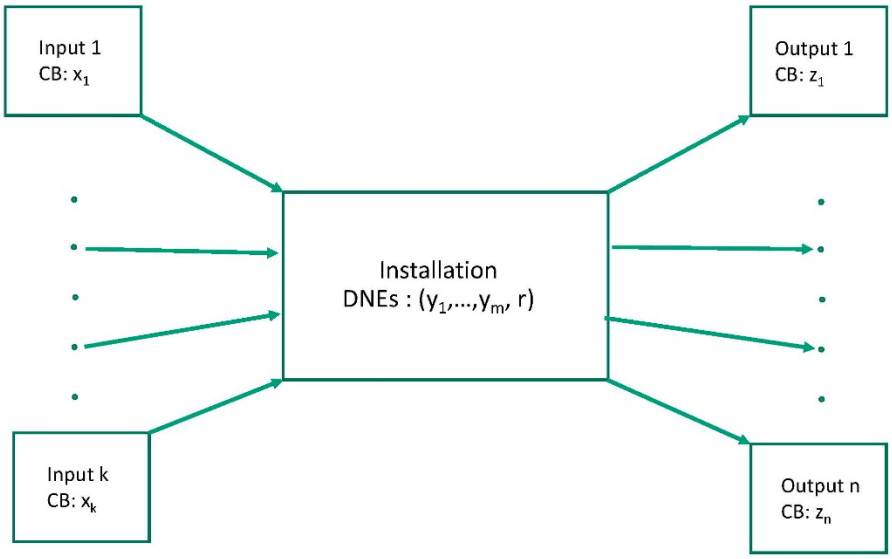

Figure 3: **Assignment of Carbon Balances to Products**

The task of assigning carbon balances (CB) to products, illustrated in Figure 3, can be conceptualized as a mapping of the form:

$$f(x_1, \ldots, x_k, y_1, \ldots, y_m, r) \rightarrow (z_1, \ldots, z_n). \quad (1)$$

Ideally, the carbon balances x_i of the different inputs were reported by the firm's suppliers, e.g., a utility disclosing the average emissions per kWh of electricity sold. Alternatively, a company must rely on secondary data for an estimate of the carbon emissions embodied in a particular production input. These production inputs will generally include both consumable inputs, e.g., parts that go into a sales product, and capital goods, e.g., machinery and equipment. For the latter, the carbon balance could correspond to a periodic depreciation charge derived from an

accrual accounting system that tracks the carbon emissions embedded in the firm's operating assets.[50]

An economically meaningful assignment rule *f(.)* must reflect the *causal relation* between the use of acquired inputs, the direct emissions emanating from particular production steps and the products going through these production steps. The task of constructing such an assignment rule is similar to that of choosing inventory costing rules that assign overhead costs to individual sales products. Activity-based costing seeks to capture this causal link in a two-step allocation process. Overhead line items are first assigned (allocated) to production activities, and in the second step the overhead costs accumulated for each activity are allocated among the different outputs. Both of these mappings require the choice of suitable allocation bases, frequently referred to as cost drivers. [51]

Assuming the carbon balance, z_i, attributed to the *i*-th product line corresponds to goods that were completed (as opposed to remaining in work-in-process), one obtains a measure of the carbon intensity of the *i*-th product line, e.g., tons of CO_2 per ton of steel produced.[52] Companies in the cement and chemicals industries have recently calculated the carbon intensity of their sales products by applying the general principles underlying inventory costing.[53,54] The German chemical company BASF has developed an online tool, referred to as Strategic CO_2 Transparency Tool (abbreviated as SCOTT), that allows management to track the carbon footprint of more than 40,000 chemical products in real time. As one Europe's largest CO_2 emitters, BASF faces increasing demands from its customers to disclose the emissions embodied in the company's sales products.[55] Similar customer demands also arise in the public sector. In evaluating the bids by potential contractors, procurement agencies in Germany have recently been directed to consider competing bids also in terms of the carbon emissions embodied in the products offered by prospective contractors.

Companies like BASF refer to their product carbon footprint measures as cradle-to-gate footprints. This label becomes most transparent in a hypothetical setting where each company

along a supply chain combines multiple production inputs into one unit of a single sales product. In such a scenario, there are no allocation issues because there is only a single variable, *z*, on the right-hand side of Figure 3. Further,

$$z = \sum_{i=1}^{k} x_i + \sum_{i=1}^{m} y_i - r. \quad (2)$$

The carbon footprint of each firm's single product then simply becomes the sum of its own direct net emissions plus the sum of the emissions embodied in inputs received from suppliers, i.e., the quantities x_i.

For multi-product firms, the aggregate cradle-to-gate footprint of the entire portfolio of products sold in any given time period yields a comprehensive metric of a company's aggregate "Upstream Scope 3" emissions. We refer to this metric as Carbon Emissions in Goods Sold (CEGS). In reporting its CEGS, a company effectively assumes responsibility for its own direct net emissions, an allocated share of those incurred by its immediate suppliers, their suppliers' suppliers, and so forth up the entire supply chain. By committing itself to reporting this metric in accordance with the TCCR standard, a company will have tangible incentives not only to reduce its own direct emissions, but also to engage with suppliers in order to reduce the carbon balances of the goods and services they supply.[56] Companies like Microsoft, for instance, have been explicit that the emissions attributed to suppliers that Microsoft includes in its Scope 3 emissions, may become a criterion for supplier selection in the future.[57]

The CEGS metric satisfies two noteworthy robustness properties. First, in contrast to the DNE metric, CEGS is largely invariant to outsourcing activities. Because the reporting entity seeks to account for all emissions embodied in the inputs that arrive at its gates, there is no benefit to shifting direct emissions from within the company's gates to the bucket of indirect upstream emissions. Second, the choice of an assignment rule f(.), illustrated in Figure 3, leaves firms with inevitable discretion in assigning carbon footprints to individual products, just as in accounting for their product costs firms have discretion in assigning overhead costs to individual products. However, provided the company is not building up or depleting inventory in the current period, this discretionary choice has no impact on the aggregate CEGS metric. If all outputs produced in a given time period are also sold, then

$$CEGS = \sum_{i=1}^{n} z_i = \sum_{i=1}^{k} x_i + \sum_{i=1}^{m} y_i - r.$$

To summarize, the metric Carbon Emissions in Goods Sold captures the upstream component of a company's Scope 3 emissions. Widespread adoption of this metric will yield significant network effects. As more firms along a supply chain adopt this measurement approach, the calculated cradle-to-gate product carbon footprints will increasingly reflect the actual direct emissions incurred by a firm's suppliers, their suppliers and so forth. The recursive nature of this measurement approach relies on local knowledge and the use of primary data at the company level. This stands in contrast to the current practice of Scope 3 reporting according to the GHG Protocol, where companies today generally rely on secondary industry-wide estimates provided by outside experts. We finally note that companies seeking to adhere to full Scope 3 according to the GHG Protocol may choose to split their overall Scope 3 figures into a measure of actual upstream emissions incurred, i.e., their CEGS, and a separate estimate of the future emissions associated with the subsequent use of the company's products.

Product Carbon Footprint Metrics

Once companies calculate the cradle-to-gate carbon footprint of their individual sales products, the TCCR framework can be applied at the product rather than the entity level. Accordingly, firms would forecast the trajectory of the carbon intensity of select products up to the year 2050 and periodically update earlier forecasts. This would allow companies like BASF to supplement their current cradle-to-gate carbon footprint metrics with a projected trajectory for future reductions. In order to fulfill a pledge of driving the aggregate CEGS metric to zero, the carbon intensity of all products would have to go to zero by 2050: in addition to the firm's own direct net emissions, the carbon balances of inputs received from suppliers would then also have to go zero.

Well ahead of the 2050 target date, consumer-oriented companies like Shell, Nestle and Total have begun to market select products as "carbon neutral".[58] Accounting for product carbon footprints according to the framework described here would enable firms to back up such claims. Specifically, any claim that the carbon intensity of a particular product has already

reached zero will be substantiated by providing product-specific line-item information on direct emissions, upstream indirect emissions and direct removals. Additional disclosures on how the firm's direct removals were allocated among the products labeled "carbon neutral" would lend further credibility to selective carbon neutrality claims.

4. Concluding Remarks

The recent wave of corporate net-zero pledges has been greeted as a significant development in the global effort to decarbonize production processes. This perspective article has argued that corporate carbon reduction pledges will become more transparent, and result in more accountability, if firms commit to a time consistent disclosure framework. Corporate disclosures in accordance with the TCCR standard will allow the public to track corporate emission forecasts, their revision over time, and the extent to which actual emissions in any given year are in line with past projections.

This paper has discussed time-consistent corporate carbon reporting in the context of alternative periodic "flow variable", i.e., Direct Net Emissions, Carbon Emissions in Goods Sold, or, the current product carbon footprint of select products. Going beyond a conventional net-zero pledge, a few companies, notably the technology firms Microsoft and Google, have articulated the more ambitious goal of "climate neutrality" which requires offsetting a company's entire legacy emissions, relative to some inception date. We note in closing that the TCCR standard is equally applicable if the "pledge metric", that is, the metric on which the pledge is based, is a stock variable, such as a firm's legacy CO_2 emissions. Such a reporting framework, however, will require the adoption of a comprehensive accrual accounting system that tracks the underlying stock and flow variables over time.

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