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Corporate Carbon and Climate Change Accounting: Application, Developments and Issues

S. Schaltegger, D. Zvezdov, E. Günther, M. Csutora and I. Alvarez

Abstract While climate change policies and negotiations are developing and scientist are urging for more action, in most countries progress remains on a low level and the macro figures indicate that climate change becomes even more critical. As a reaction to this, some advanced business leaders have initiated various actions and projects with their companies, and various regulations have been introduced by governments with varying levels of effectiveness. In this context of a mix of international initiatives, media attention, customer irritation, diverse regulatory changes and partial political lethargy, ever more companies are challenged to identify and reduce their exposure to climate change issues. Whereas the reduction of climate change emissions is an important topic, it has also become obvious that climate change is not just a future risk but is already happening. This invokes adaptation activities in addition to mitigation strategies and measures. A basic requirement to design the corporate climate strategy is the knowledge about the company's exposure as well as about options, effects and costs of emission

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reductions and adaptation measures. This is where climate change accounting as a specific kind of environmental management accounting comes into play. This introductory section outlines core questions and approaches.

1 Climate Change and Business

The natural boundaries of global prosperity are rendered visible as they are approached. One of the boundaries that have drawn broader public, political and corporate attention is climate change (EC 2007; EEA 2010; IPCC 2007; Schnellnhuber et al.2006; SwissRe 2011). It poses an eminent threat to the lives and properties of hundreds of millions of people. The negative effects of climate change are virtually everywhere: from Pacific islands like Tuvalu, where the rising sea level endangers the continued existence of whole nations, to the Alps, where the economy is hit by fewer tourists as a result of melting glaciers and a lack of snow. When nations and whole industries are confronted with a phenomenon of un-sustainability it is not astonishing that many industries, markets and companies are affected by climate change induced problems of water scarcity, soil erosion, devastatingly large fires, decreasing fish populations, floods, etc. Given the interconnectedness of industries and global trade, an impact of climate change to global social and economic systems is also likely to have an impact on those who are not directly affected.

Mankind's influence on climate and the resulting climate change have been on the political agenda since the 1970s. Numerous climate summits later, policy-makers have been unable to develop and adopt effective measures to counteract climate change (e.g. EC 2007). At the same time, the role of individuals and companies in combating climate change has become apparent. Yet, many incentives and prohibitions to regulate individual behaviour pertaining to climate impact have been deemed inefficient. Therefore, a large share of effort has been focused on business activities and the mitigation and compensation of their contribution to climate change. *Mitigation* refers to activities to reduce greenhouse gas emissions. Reducing emissions has become increasingly important because governments around the world have begun to put a price on greenhouse gas emissions: some governments have instituted carbon taxes; some have established emission reduction targets or emission caps; some have introduced emission trading systems. Even though the current price for climate change emissions is at a low level, the signal is clear for economic actors that climate issues are expected to be taken into account. At the same time, we cannot ignore another important process, the *adaptation*, concretely for those companies that are not large emitters of greenhouse gas emissions, and therefore would be mistaken in thinking that they do not need to assess climate change impacts (CPA 2004). Adaptation refers to activities reacting on the effects of climate change as it is happening.

Despite businesses' initial hesitation to tackle climate change, both the impact of companies on climate change and the effects of climate change on doing business are changing the game rules. Climate-relevant emissions have now been allotted a market price in some countries and economic regions, thereby rendering the direct costs of emission more tangible (e.g. Ratnatunga 2008). Increasing cost of climate change emissions can be expected. Also public attention has been raised, so that private and public purchasing decisions with regard to products and services have started to factor in climate change aspects in some industries and countries. Hence, in addition to the threats of not considering climate change factors sufficiently, an increasing number of businesses have recognised the benefits and opportunities of engaging with the topic. Some companies have even become leading drivers of combatting climate change and industry transformation. Their organisational change furthermore contributes to a changing competitive business environment which affects laggards, too. As a consequence ever more companies, whether proactive or lagging behind in climate management are affected and thus challenged to create a good information basis on their direct and indirect carbon emissions, but also on the impact of climate change on their business.

2 The Role of Companies in Climate Change

This section discusses the role, strategies and approaches of climate change management to outline the necessity and information requirements for climate change management accounting (also called 'carbon accounting').

2.1 Company Perceptions of Their Contribution to Climate Change

No matter what push or pull factors motivate a company to consider its options of contributing to combating climate change, corporate climate combating options can be perceived as broad or focused, depending on the perspective:

– From a *production* perspective, the company's position in the value chain determines the objectives of emissions management activities. Some authors focus on measures within a company's production processes (e.g. Schultz and Williamson 2005; von Weizsäcker et al.2009).
– Yet, a company's emissions are determined not only by its production processes but also by *product design*. Jeswani et al. (2008) describe product change and product development as possible measures to reduce emissions.
– Furthermore, *supply chain* measures, as highlighted by Kolk and Pinkse (2005) and Lee K. H (2012), can help in including indirect emissions that occur upstream and downstream in a company's value chain.
– Related to supply chains and production is the *choice of resources* which can have a substantial effect on how much CO_2 is emitted (IEA 2011). Whereas

timber from sustainable forestry can contribute to a CO_2 reduction in the atmosphere oil extraction and burning always increases atmospheric CO_2 concentrations.

- The influence of *company locations* is a further climate management perspective as locations determine commuting activities of employees and delivery distances of suppliers and distribution (Schaltegger and Csutora 2012).
- *Distributions channels* also play a role for the climate effects of distributions logistics and customer travelling (e.g. GHG 2011c). Sales locations can be close to the customer, on the "green field" or substituted with carbon intensive online shopping and distance retailing.
- *Business models* which support shared use or re-use of products, the substitution of products through services, the implementation of closed-loop systems, etc. can have a substantial effect on decreasing direct and indirectly induced CO_2 emissions of company (e.g. Bocken et al. 2014; Schaltegger et al. 2012).

In view of the extent to which companies depend on carbon resources, some companies emphasize measures that rely on the future use of carbon (e.g. Dunn 2002), while others suggest measures that are directed at the (total) substitution of carbon resources (e.g. Conference Board 2007). These two approaches reflect different mitigation strategies of climate management, whereas adaptation strategies focus on the management of the impact of climate elements, such as average temperature and precipitation, but also extreme weather events.

2.2 Corporate Climate Change Strategies: Mitigation and Adaptation

The selection of climate management measures is largely influenced by the corporate strategy, either as an adaptation or as a mitigation strategy, or a combination of both (Kolk and Pinkse 2005; Kolk et al.2008).

So far *adaptation* measures have predominated corporate practice (CDP 2012). Many companies report that they have started to consider climate change in their business strategy. However, only a small share of companies mentions a specific and systematic adaptation *strategy* (CDP 2012). If the perspective of dynamic capabilities is taken, three dimensions can be differentiated for an adaptation strategy (Busch 2010): climate knowledge absorption, climate related operational flexibility, and strategic climate integration. For specific industries these dimensions can be broken down further. For the insurance industry Mills distinguished for example seven dimensions of climate change adaptation:

- understanding the climate change problem
- building awareness and participating in public policy
- aligning terms and conditions with risk-reducing behaviour
- risk transfer mechanism/risk reducing mechanism
- new insurance products and services

– (Re)investments in climate change solutions
– financing customer improvements

The alternative response to climate change is referred to as climate change *mitigation* (cf. IPCC 2015). At the core of the mitigation mechanism are efforts to avoid greenhouse gas (GHG) emissions. Furthermore, the removal of these gases from the atmosphere by means of carbon sinks (e.g. by carbon capture and sequestering) can be subsumed to mitigation. Corporate climate change mitigation can be differentiated along the management circle (e.g. Glienke and Guenther 2015): Corporate policy defines the purpose of the mitigation activity. Corporate planning involves the identification and assessment of climate change impacts, the setting of targets, and the formulation of measures. Implementation and operation focuses on the related organisational structure and process organisation. Checking and corrective action aims at continuously monitoring and improving climate change mitigation. Finally, management reviews support top management to evaluate mitigation efforts. Interestingly enough there seems to be lack of research publications focusing on the review of the climate mitigation strategy. This could be a sign for a research gap and/or only superficially introduced climate change strategies in corporate practice and a lack of awareness in management control.

The need for a combination of mitigation and adaptation is stressed by the fact that even the most effective emission reductions would be unable to prevent further climate change impacts.

2.3 Corporate Climate Measures

The variety of perspectives results in five categories of climate impact mitigation measures for companies: technical, financial, market-related, fuel switch and emissions trading (Weinhofer and Hoffmann 2010).

Technical measures in the context of carbon management are those activities that aim at achieving emissions reduction by means of technical improvement. More often than not, these improvements are of incremental, as opposed to radical, nature. The relatively lengthy catalogue of related actions options is discussed below.

Financial measures are all measures that improve the carbon performance of company by engaging in a form of a financial transaction. Measures can be grouped in three categories: (i) acquisition of assets that balance a company's production facilities portfolio, (ii) divestment from business activities with too much current or potential carbon exposure, and (iii) investment in clean technologies, liabilities and provisions related with risk that company could have in the future, for example legal penalties witch you could incur as a consequence of noncompliance with future laws.

Market-related carbon management measures comprise activities with a potentially radical innovation character (as opposed to the mostly incremental improvements associated with developments in technology). One outcome of radical innovation can be new products which are not only substitutes for existing ones but typically change consumer behaviour and replace product purchase with the consumption of (product based) services (e.g. Hansen et al. 2009).

Switching from carbon-intensive to less carbon-intensive, carbon-neutral or even carbon-positive energy sources are a further category of measures. The catalogue of measures in this category is rather limited, although different possibilities exist. Sourcing of renewable energy is typically considered more expensive due to the higher market price of carbon-friendly energy sources compared to conventional ones (e.g. von Weizsäcker et al.2009).

The last group of measures comprises those activities that seek to either *reduce* absolute carbon emission output or reduce the cost of resulting emissions (Ratnatunga et al. 2011). A combination of the two objectives may also result in reducing overall emissions while also decreasing the relative costs of the remaining emissions.

For climate change adaptation four categories of measures can be differentiated (Fig. 1): avoid or insure, anticipate, increase flexibility, and substitute.

These measures are categorized along two dimensions (Fig. 1): one dimension is the type of climate change that could be differentiated in a first order change (changing averages) and in a second order change (change in extreme weather events). The other dimension differentiates measures along responsiveness (or inversely capital employed, time horizon, research and development time) in high and low:

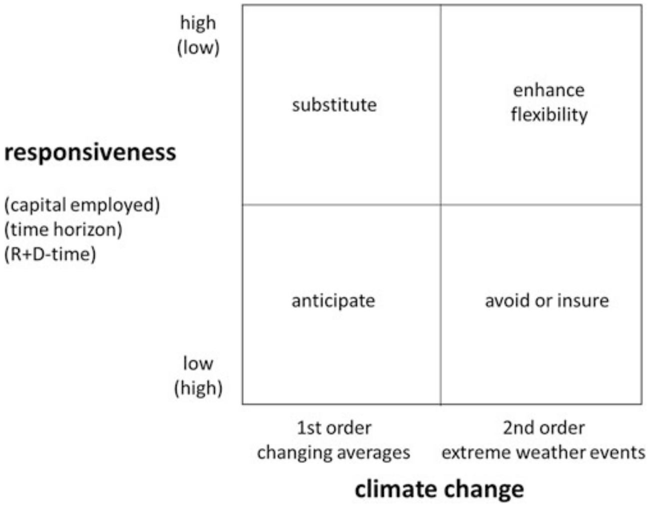

Fig. 1 Categories of climate change adaptation measures (Stechemesser et al. 2015, 132)

- *Avoidance and insurance measures* focus on business activities that allow resilience towards extreme weather events: e.g. buildings could be constructed in a way that flood or storm events will not harm the building. Alternatively future damages can be insured.
- *Anticipation measures* focus on the integration of future changes in decision making, such as the use of different roof material that will resist higher radiation.
- But also *flexible production* conditions should be considered: companies can change working hours or use the basement for storage and produce in the first floor, because machines are more difficult to be transported in case of a flood.
- Finally *substitution measures* focus on alternative raw materials, such as temperature resistant seed or different types of concrete that can tolerate higher or lower temperatures.

Depending on how broad the company management perceives its climate management responsibilities and what strategy is pursued different scopes of climate change accounting and different kinds and amounts of information are required to support implementation (Burritt and Schaltegger 2010). The identification, analysis, and evaluation of climate management activities require diverse pieces of information such as information on how climate strategy affects climate performance and financial indicators. At the same time, carbon activities also generate information. Information on carbon mitigation and adaptation activities is typically managed with accounting methods, too. However, the question how climate change accounting could be designed and developed has so far remained largely experimental and underdeveloped in the literature.

3 Scoping of Climate Change Accounting

3.1 Levels and Purposes of Climate Accounts

Corporate climate accounting is related to climate accounts at different institutional and geographical levels. Figure 2 shows that climate change issues are addressed on scientific, political-economic and corporate levels as well as on global/multinational, national and local levels (Schaltegger and Csutora 2012). Multinational, national and regional scientific climate accounts relate climate change data to political and economic levels, thus providing reference points and orientation for corporate climate accounting.

3.1.1 Corporate Carbon Accounts

Corporate climate accounting collects information relevant for the organization and its links to society and the natural environment in the context of climate. Climate accounting thus includes greenhouse gas and carbon accounts which document the

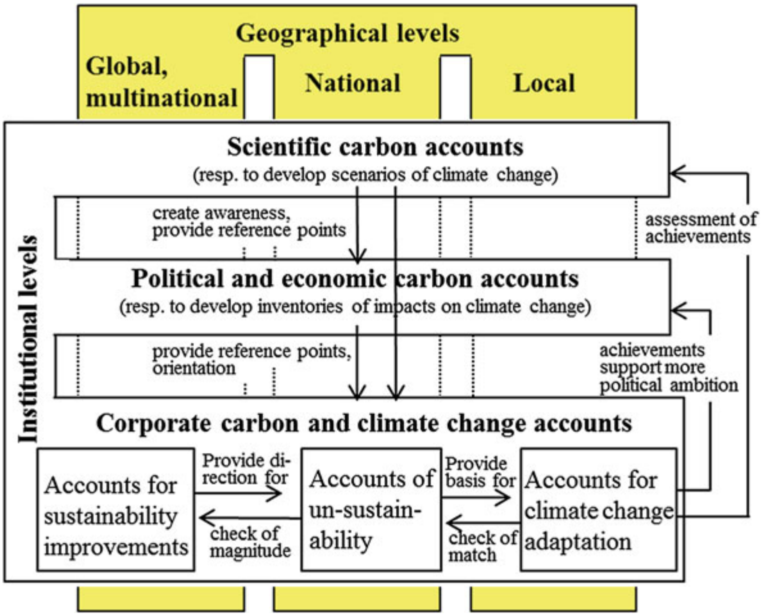

Fig. 2 Information from different levels of accounting for climate change can provide reference points for accounts (further developed based on Schaltegger and Csutora 2012, p. 4)

extent of the effects and problems, help to create awareness and provide reference points for political, economic and corporate accounts. In this view companies can take account of their climate change impacts (i.e. of the 'bad' effects contributing to un-sustainability), which provide direction for improvement measures and for planning, implementing and accounting for how effective their mitigation measures are (accounts for sustainability contributions). The interplay of corporate accounts for un-sustainability and accounts for sustainability improvements can support organizational learning processes. Corporate climate accounting can either be introduced as a means to create information for reporting to various public stakeholders or customers. Another purpose can be to initiate company internal processes of reducing the carbon footprint of the organisation and to support organizational learning processes.

The enabling function of carbon accounting (for the enabling role of accounting, see Ahrens and Chapman 2004) can thus be twofold, first, to increase transparency in the external stakeholder environment of the business (e.g. Gray 2010), and second, to identify reduction potentials, evaluate measures and support implementation (e.g. Schaltegger and Burritt 2010).

3.1.2 Climate Change Accounting

Whereas carbon accounting focuses on the impacts of companies through anthropocentric emissions measured in CO_2-equivalents, climate change accounting analyses the impacts of climate change and adaptation measures on the company. Impacts of climate change can influence costs and revenues on different levels (Bergmann et al. 2015): material losses can result from extreme weathers or not yet adapted storage conditions, employees could be less productive and thus need more work hours to finalize their tasks, depreciation can increase if climate conditions change or maintenance costs could increase in order to avoid faster depreciation. Besides these impacts on the profit and loss statement, changes in the balance sheet might occur: land might loose value, buildings might need additional investments to allow the production to continue, but also credit and insurance conditions might change due to increasing risks resulting from climate change. Economically positive effects could result from new markets for products and services.

Table 1 provides a characterization of different core functions of climate change accounting (see also bottom boxes in Fig. 1).

Depending on the relevance of the own climate change impacts some companies may focus on some accounts or establish climate accounting with all three types of accounts. Furthermore, depending on the perspective taken, a company will consider different scopes for its climate accounting.

3.2 Scopes of Climate Management Accounting

The Greenhouse Gas Protocol distinguishes three scopes of carbon accounting boundaries (GHG Protocol 2004, 2011a, b, c), that can be transferred to climate accounting, too.

- Scope 1 reflects the production and locational view as it deals with emissions directly released by the company such as originating from production, logistics and service processes owned or controlled by the company or impacts on these processes.
- Scope 2 includes indirectly caused emissions for the generation of purchased electricity. This category cannot be mirrored directly for climate accounting, even if impacts of climate change on the delivery of energy could be calculated.
- Scope 3 extends the accounting scope upstream to emissions indirectly caused through supply chains, the purchase of goods and services, and downstream, the use and waste disposal of products (e.g. EC 2003). Climate change has huge impacts on upstream and downstream activities and thus this scope can be transferred to climate change adaptation.

Figure 3 displays carbon management accounting scopes according to the GHG Protocol and in addition shows the additional scope of sustainable supply chain accounting extending the perspective over the whole supply chain (tier 1, 2, 3, etc.).

Table 1 Climate management accounting for transparency and improvement

	Carbon accounting of un-sustainability	Carbon accounting for sustainability improvements	Accounting for climate change adaptations
Core functions of carbon management accounting	Creating transparency about past and current operations	Identification of reduction potentials	Identification of most efficient adaptation projects
		Evaluation of reduction measures	Measurement of adaptation costs
	Forecasting future impacts	Support of the implementation of reduction measures	
Kind of prevailing acc. information	Physical	Physical and monetary	Monetary (and partially physical)
Physical or monetary			
Time frame	Past oriented (mostly), little future oriented information	Present and future oriented (mostly), little past oriented information	Future and present oriented information
Frequency of information	Continuously generated	Ad hoc generated project related	Ad hoc generated project related information
		Project management control supporting measures	Project cost management control supporting measures
Length of time	Long-term	Short-term and long-term	Mid and long-term

Further developed based on Schaltegger and Csutora (2012, p. 7)

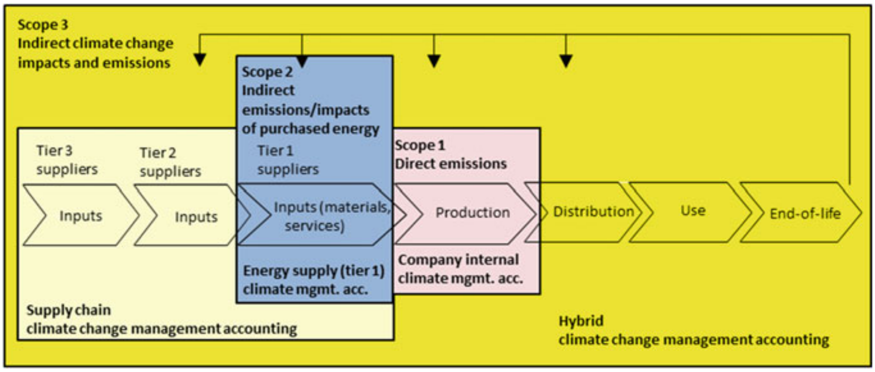

Fig. 3 Different scopes of carbon accounting address the different perspectives (based on Schaltegger and Csutora 2012, p. 11)

The allocation of emissions (in the case of accounts of un-sustainability and for sustainability improvements) resp. climate change impacts (in the case of adaptation related accounting) to scopes is a tricky issue (Wiedmann et al.2006) and depends on how corporate boundaries are defined and may also depend on whether the company applies a financial control or an operational control approach. Identifying what kind of control a company has over its operations (Emmanuel and Otley 1985)can be important in allocating emissions to scopes Table 2 provides an example for illustration.

Scope 3 emissions include induced emissions of purchased goods and services, capital goods, upstream transportation and distribution, business travels, employee commuting, upstream leased assets, transportation, use of sold products, end-of-life treatment of products, etc. An estimation of Huang et al. (2009) suggests that supply chain-related emissions could account for even as much as 75 % of the total GHG emissions induced by the company. Thus significant carbon mitigation strategies cannot be revealed if scope 3 emissions are neglected (Matthews et al. 2008). The climate change impact of downstream industries, e.g. service industries, can be as big as the impact of manufacturing sectors, if indirect impacts are accounted for (Rosenblum et al. 2000).

While scope 1 and scope 2 emissions can usually be calculated or estimated using company data, calculating full range of scope 3 emissions require upstream or downstream data not directly available to the reporting company. Hybrid accounting, also called environmentally extended input-output analysis provides estimation for Scope 3 carbon emissions by approximating upstream supplier emission data with economic sector average and by approximating carbon emission flows among economic actors with the associated monetary flows (Crawford 2008; Lenzen et al. 2009; Suh et al. 2004). Total embedded carbon emission is gained by combining sector carbon emission data and monetary symmetric input-output tables and applying the procedure developed by Leontief, and proposed by Bicknell et al. (1998), Ferng (2001), Lenzen (2009) and Wiedmann et al. (2006, 2009).

Table 2 Accounting for truck emissions depending on the management control approach applied

Cases	Financial control approach		Operational control approach	
	Fleet is owned by the company	Fleet is not owned by the company (leased)	Operation of the fleet is directed by the company	Operation of the fleet is not managed by the company (operated by a subcontractor)
Emissions of a petrol fuelled forklift	Scope 1	Scope 3	Scope 1	Scope 3
Indirect emissions of an electric forklift	Scope 2	Scope 3	Scope 2	Scope 3

Controlling scope 3 emissions is possible by changing the product design for reducing downstream consumer impacts, green procurement of intermediate products and raw materials or by better auditing suppliers (Kral et al. 2009). The high proportion of scope 3 emissions and the high potential for controlling them spotlight the importance of green supply chain management (Sarkis 2003; Lee K. H 2012) as well as hybrid accounting techniques. The results of hybrid input-output and LCA analysis can be used to inform companies on which activities they should focus their emissions reduction strategies regarding the aspects of external relationship with suppliers and consumers (Lenzen et al. 2009).

Hybrid accounting is able to capture the embedded emission of purchased products and services of upstream suppliers and less frequently downstream impacts, too. Input-output assisted life-cycle cost accounting (IO-LCA) or hybrid accounting of products also has been gaining attention in the field of material flow cost accounting (FEE2002; Jasch 2009). It combines the traditional inventory analysis methods with input-output analysis in order to mitigate the limitations of available data sources and the assessment methods (Crawford 2008).

These limitations of hybrid accounting have been discussed by several authors who argue that the results are based on statistical average and that they depend on how typical the studied product or company is in relation to the sector where it appears (Finnveden et al. 2009; Suh and Huppes 2002, 2005). Double accounting of Scope 3 impacts in tiered inventories by different actors is likely and needs be managed explicitly (Lenzen 2009). Hybrid accounting should not be used for convenience reasons when physical emission data is available at reasonable cost. Thus, hybrid accounting can be seen as an auxiliary method to conventional MFCA or LCA studies and should be used when making a rough estimation is more rewarding than making no estimation at all (Lee S. 2012).

Corporate carbon management accounting (i.e. accounting for un-sustainability and accounting for sustainability solutions) may support all functions and managerial decision-making situations with specialized accounting tools. For climate change accounting the procedures could be similar: in scope 1 the company analyses the impacts of the changes of different climate change issues on core business; in scope 2 the resilience of the energy supply can be analysed, and in scope 3 all upstream and downstream activities can be examined systematically for potential impacts of climate change. Table 3 provides an example how such a climate change adaptation oriented accounting could be supported with an assessment of climate change impacts on scope 1–3 accounts.

4 Information Requirements for Decision-Making in the Context of Climate Strategies

To develop and implement suitable measures for improving their carbon performance resp. climate change adaptation performance, companies need information. The complexity of the issue requires diversified information: starting from

Table 3 Assessment of a climate change impacts to support adaptation oriented accounting

Climate change element	Impact on scope 1	Impact on scope 2	Impact on scope 3
Average temperature per year in °C			
Temperature in summer in °C, April–September			
Temperature in winter in °C, October–March			
Number of summer days, max. temperature 25 °C and more			
Number of hot days, max. temperature 30 °C and more			
Number of tropical nights, min. temperature 20 °C and more			
Number of ice days, max. temperature below 0 °C			
Number of frost days, min. temperature below 0 °C			
Heating degree days, K d/a, measure for heating energy demand during heating period			
Cooling degree days, K d/a, measure for cooling energy demand			
Average precipitation in mm			
Average precipitation in summer in mm, April–September			
Average precipitation in winter in mm, October–March			
Number of dry day in summer, precipitation below 1 mm			
Number of days with heavy precipitation in summer, precipitation above 20 mm			
Potential evaporation, mm, potential maximum			
Climatic water balance (mm, precipitation minus potential evaporation)			
global radiation in kWh/m^2			
Duration of vegetation period (number of days)			
Flood			
Heat waves			
Cold waves			
Drought			
Storm			

information to assess carbon exposure down to meeting the various information demands of different—internal and external—information addressees.

The diversity of decisions, as described in the previous section, requires diverse carbon information in terms of granularity, function, relevance, etc. An important information requirement is the *granularity of information* (Fig. 4). In addition to the aggregated information a carbon and climate change accounting system should be

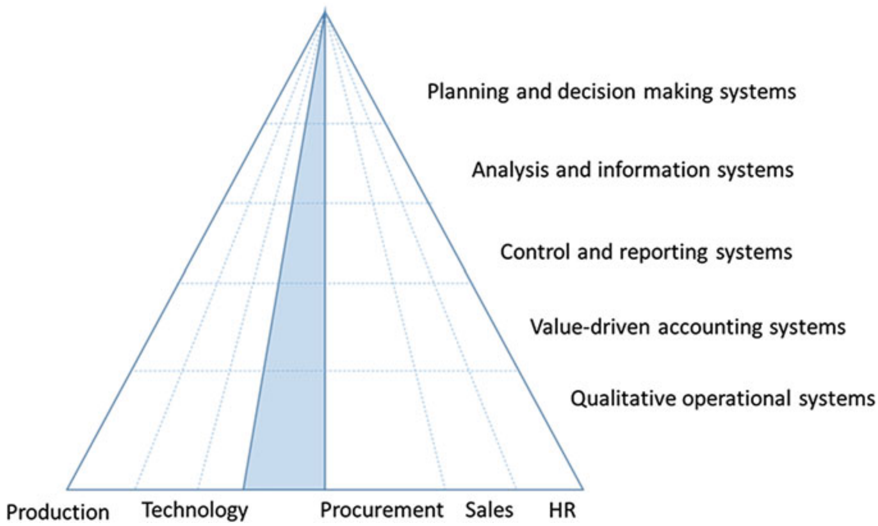

Fig. 4 Level of detail of climate accounting information (translated from Hufschlag 2010)

able to provide, detailed information on quantities and costs is also important. This could help avoid the need to refer to the original data source for obtaining carbon-related information. Bennett et al. (2013) conclude that sustainability (and thus climate-related) information often lacks granularity, which indicates a gap in communications between information providers and users. This can be interpreted as providers being unaware of the importance of granularity and therefore reporting only what is requested. At the same time information users may be unaware that the information could be provided in this granularity and therefore do not request it. As a result, climate change management may be carried out based on only a limited set of information.

The granularity property also applies to information in the context of providing top management with aggregated information for designing and fulfilling strategic objectives whereas operational management would typically need much more detail information with regard to processes, products (e.g. Carbon Trust 2008) and sites.

5 Difficulties and Methods in Accounting for Tracking and Tracing Climate Performance

5.1 Difficulties

Managing climate-related information has remained largely under-researched to date. Yet, indication of various difficulties can be obtained from extant literature. Table 4 summarises important challenges in terms of information quality based on

Table 4 The five principles of GHG accounting and reporting and their implications for corporate decision-makers

Difficulty	Explanation	What it means for internal and external decision-makers
Relevance	Ensure the GHG inventory appropriately reflects the GHG emissions and the climate change impacts of the company are recorded properly to serve the decision-making needs of users—both internal and external to the company	The information produced should be such drives climate performance (as opposed to purely diagnostic purposes)
Completeness	Account for and report on all GHG emission sources and activities and all climate change impacts within the chosen inventory boundary. Disclose and justify any specific exclusions	Comprehensive climate information on a large number of various products and processes
Consistency	Use consistent methodologies to allow for meaningful comparisons of emissions and impacts over time. Transparently document any changes to the data, inventory boundary, methods, or any other relevant factors in the time series	The various products and processes are based on the same data and calculation methods to enable comparisons
Transparency	Address all relevant issues in a factual and coherent manner, based on a clear audit trail. Disclose any relevant assumptions and make appropriate references to the accounting and calculation methodologies and data sources used	The assumptions based upon which information is collected are clearly disclosed to decision-makers, and, ideally, accord with established standards
Accuracy	Ensure that the quantification of GHG emissions is systematically neither over nor under actual emissions, as far as can be judged, and that uncertainties are reduced as far as practicable. Record climate change impacts in a traceable manner. Achieve sufficient accuracy to enable users to make decisions with reasonable assurance as to the integrity of the reported information	Climate information accuracy is achieved by using measured (as opposed to calculated or estimated) data

Based on WBSCD and WRI (2004, p. 7)

five principles of GHG accounting and reporting proposed by the World Business Council for Sustainable Development and the World Resource Institute (WBSCD and WRI 2004). The five principles—relevance, completeness, consistency, transparency and accuracy—have been discussed for the last two decades in the environmental and sustainability management accounting and reporting research (e.g. Burritt et al. 2002; Schaltegger and Burritt 2000; GRI 2011) and can be considered as commonly accepted.

Information *relevance* is an issue in the context of a complex topic in particular. Extant research identifies that climate information is collected in organisation also for reasons beyond decision-making (Bennett et al. 2013; Burritt et al. 2011a, b). Due to the uncertainty inherent to the future relevance of the topic, using climate information is not a straightforward task. Scenarios regarding the issue in the future vary from "carbon emissions have a clear-cut price on the market" to "national policy will change with the next government". The issue is amplified by the spectrum between the former two extremes, for example: carbon taxation may remain in place, yet society's attention will be diverted from it. For climate change impacts regional scenarios can be used, because international data does not reflect the specific situation a company faces. Some stakeholders, including shareholders, perceive environmental issues to be material to their decision-making processes, and they seek information on these climate change related activities (Deegan and Rankin 1997). However, the creation and consideration of this information is more complex than the preparation of financial statements, for various reasons (FEE 2006, 2002): (i) The report is not prepared from just one viewpoint (in financial accounting traditionally that of the shareholders) but is relevant to a broad range of different stakeholders; (ii) the report may include less quantitative and more non-financial, qualitative information; and (iii) the criteria are less developed than regulations and standards that determine financial reporting. In this context, Lamberton (2005) states that monetary units are relevant for assessing economic performance, but are not appropriate for assessing social or environmental performance, as consequence the accountant's tradition to monetise social and ecological impacts seriously misrepresenting and understating the significance of these issues.

Completeness in the context of climate information can be considered particularly challenging. The complexity of the climate challenge is a key factor for climate accounting as pointed out in previous research (Oppewal and Klabbers 2003) as conflicts between information completeness and task simplicity often exist. One aspect that complicates the completeness of climate information is the probability related to a risk. Disclosure of a risk with a low probability rate but potential high impact should also be carefully considered (CPA 2014) as this situation is very relevant for various environmental issues where some actions could cause large environmental and economic impacts although the probability is low. O'Dwyer and Owen (2005) conclude that completeness is very rarely considered in sustainability reports and that it remains unclear whether enough information is provided to support users in their decision making process. For Gray (2000, p. 248) auditors rarely, if ever, comment on the degree of completeness. He concludes that readers could easily be fooled and believe that attestation of auditors and verifiers means that the report is a complete, true and fair representation of the climate impacts of the organization. While this analysis has its merits, in practice the problem is to oversee all direct and indirect effects and scopes with regard to climate change impacts. Thus, even when managers are highly motivated and willing to create a complete account of the climate impacts, creating completeness is also a considerable practical challenge of mere information quantity and complexity.

Climate information *consistency* is a further challenge if climate change related information is to provide support for informed decisions. Consistency in the recognition, measurement and presentation of environmental information is essential to track developments over time and to make comparisons between products, processes, sites, companies, etc. Consistency should first of all be established internally, determined by the information needs of the enterprise's users (CICA 2008). Caution is needed when seeking to benchmark between enterprises within the same sector as even apparently minor differences in processes, products or locations can be significant in terms of environmental effect (FEE 2000). The diversity of climate information may have manifold influences on the conclusions drawn from it. On the one hand, future implications of CO_2 emissions for example in terms of economic risk can vary on a micro and macro level over time. On the other hand, the scope of information is also a challenge to secure consistency as some subsidiaries or companies may want to inform about all production sites in their perimeter of consolidation while others may refrain from this (for an in-depth discussion of this issue see Schaltegger and Burritt 2000, 347), or some companies would inform about the impacts of all companies in their supply chains while others would not consider the supply chain at all. Finally, the methods and scope to forecast greenhouse gas effects need to be considered. While it has become common to consider a one hundred year period, other time periods are also possible and may have a substantial impact on assessments. This problem has been raised for example by CPA Australia (2004) who states that questions of scope and time are typically answered by managers without consulting stakeholders, while often no clear indication of restrictions in scope is provided in sustainability reports. While such information can be provided in climate and sustainability reporting it remains uncertain whether and to what extent such scoping issues are understood and considered by which stakeholders. The guidelines provided by the GHG Protocol may help to reduce problems of consistency, although uncertainties and value decisions are still required and cannot be eliminated completely.

Transparency is a key factor, especially for the decision making of the external stakeholders. Moneva et al. (2006) considers transparency the core issue of accountability. Transparency refers to the ability of an informed observer to understand the system with a reasonable amount of effort and in a reasonable amount of time. This view has been transferred from financial accounting standards where standards have developed for many decades (CDSB 2010). A similarly comprehensive standardisation process and system does not exist for climate accounting (for environmental accounting in general see Schaltegger 1997; Schaltegger and Burritt 2000). As a result, still various different calculation methods and data sources exist and are used in climate accounting and reporting. Companies which have already established carbon and climate change accounting systems may face the problem to link or converge them with emerging standards such as the GHG Protocol (see e.g. Gibassier and Schaltegger 2015). Apart from company-internal accounting challenges the lack of standardised calculations complicates audit processes and at the same time reduces comparability and transparency. It also makes it difficult to understand the information with a reasonable amount of effort in a reasonable amount of time. Similar to the GRI guidelines, the GHG Protocol provides a first step towards more standardized accounting and reporting for climate change issues.

Accuracy requires that the reported information is sufficiently precise, representative and detailed for users to assess the organization's performance. The characteristics that determine accuracy vary according to the nature of the information and the user. This complicates the management of information accuracy in climate accounting, firstly, because of the complexity and the invariable needed value assessments of information creation, and secondly, because of the differences between the information requirements of users.

Another challenge is related to the *assurance practices*. Sustainability assurance practices have been characterised by inconsistencies (Owen 2007, 178) and are only converging slowly. Report users may face uncertainties in understanding how the assurance providers reviewed the reports and what the meaning of their conclusions is. The development of assurance standards is thus of high relevance to effectively deal with the challenges mentioned above.

5.2 Methods: Climate Management Accounting

To reflect the discussed challenges, various methods in climate accounting can be considered in decision-making. Based on the Environmental Management Accounting framework, Burritt et al. (2011a, b, 2002) propose a taxonomy for climate management accounting decision situations which identifies four key attributes of climate management information. These attributes help to define the information needs of company-internal decision makers and external stakeholders:

- monetary or non-monetary information
- the time frame—past or future
- the length of time frame—short or long-term
- the routineness of information provision—regular or ad hoc (one-off)

The framework thus provides the foundation for a systematic analysis of the scope, range and potential variability of climate accounting structures and processes.

6 Outlook

Despite the high relevance of climate change for companies, corporate practices to counteract and adapt to climate change have so far been documented as scarce. Probably the major question that arises from this is what factors inhibit corporate managers to actively establish climate accounting and to effectively combat climate change. Furthermore, the large spectrum of climate accounting tools and mechanisms described in this publication appears to be applied only by few very proactive companies, so far. Therefore, key issues remain to be resolved include:

– Gaining a better understanding of what companies consider to be their climate performance. There may be a discrepancy between what is perceived to be corporate climate performance by researchers and what companies try to achieve. Previous attempts to understand this issue, such as analysing reports, investigating performance indicators or discussing single case studies have so far not been able to address the topic adequately.
– The above discussion also shows that producing a more vivid, in-depth account of how businesses consider climate information in their operations is needed. The available research seems to fall short of revealing decisive details that help understand business requirements and manager attitudes towards climate accounting practice.
– The complexity of climate accounting as presented in Sect. 3.2 reveals critical interdependencies in the network of economic actors. Therefore, the understanding of inter-organisational, climate change related efforts needs to be improved. Examples of such an inter-organisational focus include supply-chains and the interactions between the actors involved in economic networks.
– The development of standards of climate accounting, auditing and assurance has only started recently and needs further improvement. While standards seem to be inevitably needed, the challenge will include ensuring that standardisation does not get overcomplicated and bureaucratic. Financial reporting standards and related auditing and assurance processes have in spite of a large number of specific standards and regulation not been able to prevent fraud and financial disasters. Similarly, for climate accounting, the expectations should not be set too high, as the transparency and accountability function of climate accounting and reporting may be more difficult to achieve and less important for sustainable development than often hoped for.
– If the role and potential effect of climate management accounting to help decision makers in gaining motivation, information and support to improve the corporate climate performance is larger than assumed so far then research and practice are challenged to develop climate accounting methods and processes which create effective outcomes in corporate practice.

Despite the growing momentum of the on-going discussion on climate change and climate accounting, there is still a substantial distance to walk. The following section gives an overview of how this volume contributes to shedding some light on the issues and thus may help in propelling corporate climate accounting.

7 Book Structure

This section draws the attention to various challenges in applying existing climate accounting approaches and developing new ones. The following chapters focus on individual aspects of these issues and are organised in three sections.

Section I provides an overview of literature and practices of corporate climate accounting. A literature review on carbon management accounting conducted by *Dimitar Zvezdov and Stefan Schaltegger* investigates documented corporate practices. In view of the observation that methods for managing information on corporate carbon performance have hardly been discussed, the question arises as to what decision situations a performance oriented carbon management accounting could support. The analysis conducted shows that the existing contributions on carbon management accounting (CMA) methods only support few decision situations, still leaving many areas open for future research and practice. This chapter highlights the need for decision-oriented research that enables CMA to fulfil its objective, i.e. to contribute to the efficient and effective reduction of carbon emissions.

Chapter "Decision Support Through Carbon Management Accounting—A Framework-Based Literature Review" by *Gábor Harangozó*, *Anna Széchy and Gyula Zilahy reviews the literature on corporate footprint indicators*. Current practices in the area follow different approaches to organizational level footprint concepts. This contribution therefore takes the discussion a step further by conceptualising less used footprints and their integration into sustainability management accounting.

Section II highlights principles and applications of climate accounting. The contribution by *Eduardo Ortas*, *Isabel Gallego-Álvarez*, *Igor Álvarez and José M. Moneva analyses* on the one hand the *different carbon accounting regulations* existing on the international level. On the other hand from a corporate perspective the chapter draws an account of the *main practical carbon accounting principles and applications in different industries.*

Francisco Ascui and Matthew Brander identify in Chap. "Corporate Sustainability Footprints—A Review of Current Practices" a gap in research by *distinguishing between attributional and consequential carbon accounting methods*. The authors therefore explore the nature of the attributional-consequential distinction and its applicability to corporate climate accounting. In addition, the concept of framing is used to help explain how the distinction has developed within the field of LCA.

Despite its tradition, environmental management accounting has hardly been researched as an innovation. *Delphine Gibassier* focuses on the *implementation phase of the innovation cycle* in the pursuit of an answer to the question *of how a radically new EMA innovation can be implemented in a company*. Consequently, this chapter develops a case study of the implementation of carbon accounting in a French multinational, and explores the different factors that led to the successful implementation of the innovation.

Section III comprises contributions that extend climate accounting practices. Against a backdrop of increasingly globalised supply chains, *Zsófia Vetőné Mózner discusses accounting for indirect carbon emissions embodied in different stages of the supply chain.* The chapter examines the relevance of using hybrid input-output analysis to reveal the indirect impacts in the supply chains of different economic sectors.

Chapter "Carbon Accounting in Long Supply Chain Industries" investigates the timing of voluntary greenhouse gas (GHG) reporting and corporate stakeholder orientations. For this, *Nele Glienke analyses corporate participation in* the best known voluntary initiative on climate accounting and reporting, *the Carbon Disclosure Project (CDP)*, at two points in time.

Section IV highlights the financial implications and carbon accounting. The literature review Stefan Lewandowski conducts focuses on how carbon emission levels affect corporate financial performance. The chapter finds that modelling the relationship between carbon emission levels and CFP is a complex task. This complexity can be illustrated by methodological differences between the studies included in the review which, in turn, may systematically influence the results. Therefore, a set options for methodological enhancements is suggested which may guide further inquiries into the relationship between carbon emission levels and CFP.

Anne Stechemesser, *Kristin Bergmann and Edeltraud Günther* conduct a *content analysis* based on 57 in-depth expert interviews with CEOs of different industry sectors in one distinct region of Western Europe. The chapter contributes to accounting field by conducting the *first comprehensive study on how climate change impacts and related climate change adaptation measures influence conventional financial accounting.*

The concluding chapter explores the motivation behind potential carbon emission accounting fraud by corporations. *Shamima Haque and Aziz Islam* identify several different *possible risks of carbon emission accounting fraud* which have remained mostly overlooked by researchers to date, despite the fact that such frauds have a negative impact on a country's economy as well as the real purpose of mitigating carbon emissions. The chapter offers discussion of some potential risks of carbon emission accounting fraud as well as related prevention policy.

An edited volume can always just reflect a certain stage of research and practice. It provides a flashlight into some areas which are currently examined in more depth. We hope that this edited volume does not just provide an account of current research activities but will also spurt and contribute to the further development of corporate climate accounting research and practice. The contributions show clearly that the walk towards combatting climate change is still a long one.

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Decision Support Through Carbon Management Accounting—A Framework-Based Literature Review

Dimitar Zvezdov and Stefan Schaltegger

Abstract Purpose: Managing corporate carbon performance has seen a rapid development as a topic for the past decade. To effectively reduce corporate climate change impacts requires decisions on tracking and tracing of carbon emissions in a systematic manner. Yet, methods to manage information on corporate carbon performance have hardly been discussed in the extant literature. Whilst the global greenhouse gas emissions are further increasing, the total amount of corporate emissions has only decreased in some advanced companies. This raises the question of what decision situations a performance oriented carbon management accounting could support and in which areas research could be further developed to support carbon management efficiently and effectively. **Method**: A literature review was conducted to identify the current state of development of CMA. Relevant publications were analysed by means of taxonomic analysis. **Findings**: The analysis of academic CMA publications shows that the existing contributions on CMA methods only support few decision situations, still leaving many areas open for future research and practice. **Implications**: This chapter highlights the need for decision oriented research that enables CMA to fulfil its objective, i.e. to contribute to the efficient and effective reduction of carbon emissions.

1 Highly Topical, Yet Under-Researched

For the last couple of years, carbon management has seen a notable uptake as a topic in corporate practice (Bennett et al. 2013). To effectively manage carbon performance, accurate carbon information and thus its management with carbon

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accounting methods play an important role (Burritt et al. 2011). This necessitates a review of the current corporate carbon management accounting (CMA) literature and its contributions to supporting management decisions.

Many environmental accounting publications mention carbon management accounting as an exemplary (Ascui 2014; Ascui and Lovell 2012; Lohmann 2009; Schaltegger et al. 2013). In a review of over 800 publications on environmental management accounting, carbon accounting has even been identified as one of the most discussed themes (Schaltegger et al. 2013). Two reviews on the wider area of carbon accounting (Ascui 2014; Stechemesser and Günther 2012) provide a broad overview of the literature, including macro-economic accounting approaches. Extant literature is dominated by case studies and shows that various companies have discovered (at least some of) the potential benefits of carbon accounting (Ascui and Lovell 2012). Whereas these two existing reviews shed light on the extent to which the topic is of relevance to society in general and businesses in particular, they both reveal that carbon management accounting has remained largely under-researched. Ascui (2014) classifies most carbon accounting publications (56 out of 89 in total) as part of "carbon management accounting". Yet, only four publications are seen to belong to carbon management accounting at the organisational level with the remaining 52 approaches focusing on economies or the global level.

Despite the considerable attention climate change has gained for the past decade, no overview exists of what management decision situations are particularly supported with academic and professional literature on carbon accounting.

This chapter approaches the gap by reviewing the carbon management accounting literature in view of a decision-oriented framework (Burritt et al. 2002, 2011) and by bringing together diverging perspectives discussed in the extant literature. The chapter thus investigates what decision situations have been documented in carbon management accounting practice and research. The result is an overview that allows identifying areas of carbon accounting application that have not been scrutinised yet. Comparing the corporate carbon accounting literature and documentation on company cases (e.g. Lee 2011) with the range of possible carbon accounting applications unveils 'blind spots'. Neglected, yet important decision situations are uncovered and discussed with regard to future research. This review thus supports developing these research areas and enables companies to manage their carbon performance more efficiently and effectively. This chapter also develops several propositions that can serve as the basis for building hypotheses to further advance research on the application of CMA.

This chapter proceeds as follows. Section 2 frames the issue in the context of the extant CMA literature. Section 3 describes the methodology adopted in conducting the empirical part of the research. Section 4 presents the results of the literature review and discusses key findings. Section 5 discusses CMA in the context of efficiency and provides several implications for further research. The concluding section sketches a path to enabling CMA to contribute to its original purpose.

2 What We Know About CMA—A Literature Review

2.1 The Role of Accounting in Managing Carbon Performance

Despite its relatively short history, carbon management has been of concern to various domains in organisations. No matter whether production (Bunse et al. 2011), procurement (Vickers et al. 2009), logistics (McKinnon 2010; Lee 2011) or risk management, all departments and business units can benefit from information on the existing amount of carbon emissions, their sources and drivers, and the assessment of options to reduce carbon impacts (Burritt et al. 2011). Managing carbon issues and performance is thus strongly linked to accounting for carbon information.

2.2 Purposes of CMA

On the one hand, carbon management comprises activities related to the coordination of activities to achieve a resource-efficient (i.e. under consideration of time and resources spent) and effective reduction of carbon emissions. On the other hand, carbon management can be defined as those activities that aim to secure the success of an organisation by managing carbon emissions (efficiently and effectively). CMA therefore aims to support managing carbon performance with regard to both perspectives, environmental effectiveness and economic efficiency (cf. Schaltegger and Csutora 2012; Stechemesser and Günther 2012).

Okereke (2007) identifies five groups of motivations to deal with carbon management. Legitimacy Credibility has been seen as an important motivation underpinning a given company's carbon management endeavours. Furthermore, cost reduction has been identified as another reason. More recent developments in the ethical discourse place ethical considerations as another relevant factor for managing carbon performance. Furthermore, chief executives have increasingly considered climate change as a matter of fiduciary concern (e.g. Hoffman 2006). Last but not least, a number of the FTSE companies have begun to emphasise the need to move away from seeing climate change only as a risk towards viewing it as also presenting business opportunities (e.g. Okereke 2007).

Creating carbon information by means of accounting techniques and systems enables managers to gain a relative advantage in performing their managerial tasks and attaining the corporate objectives. The purpose of CMA, in particular, should therefore be providing managers with information that assists corporate decision-making related to carbon emissions. In view of the above incentives for carbon management, Schaltegger and Csutora (2012) describe CMA as having the following objectives:

- Creating transparency and taking account of "un-sustainability" of the past and current operations.
- Forecasting future greenhouse gas emissions
- Identifying reduction potentials and evaluation of reduction measures:
- Providing support of the implementation of carbon management measures

2.3 The CMA Framework

To systematise the analysis of the carbon management literature and its contribution to support different management decision situations, this research is framed within the CMA framework (Table 1) proposed by Burritt et al. (2011). Based on the more general environmental management accounting framework proposed by Burritt et al. (2002), this framework breaks carbon management information down into four dimension: i) the nature of the information—physical or monetary; ii) the time frame of decision-making—past, present and future; iii) the length of time frame, that is, short-term or long-term; and vi) the routineness of the information supplied —regular or ad hoc.

Table 1 The CMA Framework (Burritt et al. 2011, 82)

		Carbon management accounting (CMA) Framework			
		Monetary carbon accounting		Physical carbon accounting	
		Short term	Long term	Short term	Long term
Past oriented	Routinely generated	1. Carbon cost accounting	2. Carbon capital expenditure accounting	3. Carbon flow accounting	4. Carbon capital impact accounting
	Ad hoc	5. Ex post assessment of short term/relevant carbon costing decisions	6. Ex post assessment of carbon reducing investments	7. Ex post assessment of short term carbon impacts	8. Ex post assessment of physical carbon investment appraisal
Future oriented	Routinely generated	9. Monetary carbon operational budgeting	10. Carbon long term financial planning	11. Physical carbon budgeting	12. Long term physical carbon planning
	Ad hoc	13. Relevant carbon costing	14. Monetary carbon project investment appraisal	15. Carbon impact budgeting	16. Physical environmental investment appraisal

2.4 Carbon Accounting for Eco-Efficiency

For an environmentally friendly change to be economically viable, it needs to be more efficient than the practice that it substitutes (Andrews 2006). This problem has been among the central research themes in environmental management accounting literature for the past two decades (e.g. Bennett et al. 2013; Schaltegger et al. 2013). Probably the most relevant term and concept in this context is eco-efficiency (Schaltegger and Sturm 1990; Schmidheiny 1992; WBCSD 2000).

The concept of eco-efficiency was introduced into (environmental) management to extend the basic concept of efficiency (Schaltegger and Sturm 1990; Schmidheiny and BCSD 1992; Schmidt-Bleek 1994; von Weizsäcker et al. 1997, 2009; Hawken et al. 1999). Although defining eco-efficiency and finding a way to measure it has been considered "difficult" (Britt et al. 2011) since its introduction, several different definitions and methods have been proposed (e.g. Schaltegger 1998). Generally, efficiency refers to producing the maximum number of output with the least input. Eco-efficiency, in the context of carbon management, has a slightly different meaning.

With few exceptions, the production of goods and services (as well as their use and disposal) inevitably generates carbon emissions. These carbon emissions are undesired outputs. Therefore, eco-efficiency, or more specifically carbon efficiency, refers to the value created by a product or service measured against the amount of carbon emissions caused. Carbon efficiency thus serves as a score to enable companies track and make progress in being carbon efficient.

Several authors have discussed eco-efficiency and what it entails. Derwall et al. (2005) interpret it "as the economic value a company creates relative to the waste it generates". For Huppes and Ishikawa (2005) eco-efficiency pursues the "general goal of creating value while decreasing environmental impact". These definitions are very similar and revolve around the basic idea that being eco-efficient means benefitting the environment while being economically successful (Schaltegger 1997).

Based on the CMA framework this paper examines what decision situations the existing carbon management accounting literature covers and deals with.

3 Research Methodology

To develop a research synthesis of the existing CMA literature (e.g. Onwuegbuzie et al. 2012), we conducted a literature review of all publications that explicitly refer to *organisational* CMA activities. Analysed publications include articles in academic journals as well as related professional literature such as reports of accounting bodies and consulting companies.

The data collection consisted of two complementary search strategies. Firstly, searches were executed in the academic search engine "google scholar". In addition, searches were run in the academic publication databases *EBSCO*, *JSTOR* and *Thomson Reuters Web of Science*. The search terms used are shown in Table 1. The search was conducted for every possible combination of the left and the right side of the table (Table 2).

Subsequently, further publications were identified by means of snowball sampling (Biernacki and Waldorf 1981). We adopted both forward and backward snowball sampling. In the latter approach, the references of already identified publications were scanned manually to identify referenced further relevant publications. Forward sampling was used to identify papers that have cited the identified publications.

The list of identified publications was then manually screened to sort out those publications that fall outside the scope of this literature review. Given the focus on carbon management accounting at the organisation level, several decision with regard to the publication scope were made. Excluded were:

- publications not related to managerial or corporate activities, such as on carbon accounting for buildings (e.g. Shao et al. 2014)
- publications in the domain of natural sciences (e.g. Cacho et al. 2003)
- publications strictly related to carbon footprinting for communication purposes (e.g. Scipioni et al. 2012)
- assurance- and verification-related publications (e.g. Martinov-Bennie 2012)
- publications related to the larger field of sustainability and environmental accounting which do not specifically deal with CMA in depth (e.g. Burritt and Schaltegger 2012)
- publications focused on carbon management (rather than carbon management accounting; e.g. Bradley et al. 2013)
- pedagogical discussions of carbon accounting (e.g. De Aguiar and Fearfull 2010)

This approach to data collection resulted in 31 publications, presented in Table 3.

Subsequent data analysis was conducted by means of taxonomic analysis. The primary purpose of this method is creating a classification system that categorizes the domains in a discipline or a research field to help the literature reviewer understand the relationships among the domains (Onwuegbuzie et al. 2012). Thus, a

Table 2 Search terms

Carbon	Accounting
Climate	Management
Emission	Footprint
Greenhouse gas	Allowance
GHG	
CO_2	

Table 3 Identified CMA publications

Title	**Authors**	**Journal**
Carbon reporting: does it matter?	Haigh and Shapiro (2012)	AAAJ
CO_2 emission reduction for Japanese petrochemicals	Gielen et al. (2002)	JCP
Climate change performance measurement, control and accountability in English local authority areas	Cooper and Pearce (2011)	AAAJ
Commercial local area resource and emissions modelling—navigating towards new perspectives and applications	Bradley et al. (2013)	JCP
Carbon trading: accounting and reporting issues	Bebbington and Larrinaga-González (2008)	EAR
Carbon accounting Negotiating accuracy, consistency and certainty across organisational fields	Bowen and Wittneben (2011)	AAAJ
Carbon management accounting: explaining practice in leading German companies	Burritt et al. (2011)	AAR
The European emissions trading scheme: an exploratory study of how companies learn to account for carbon	Engels (2009)	AOS
Carbon Footprint as a Basis for a Cleaner Research Institute in Mexico	Güereca et al. (2013)	JCP
Carbon accounting for supply chain management in the automobile industry	Lee (2012)	JCP
Carbon accounting and carbon footprint—more than just diced results?	Schmidt (2009)	IJCCSM
Research on the carbon footprint of beer; beverage industry environmental roundtable	BIER (2013)	Report
Uncertainty and variability in carbon footprinting for electronics case study of an IBM rack-mount server	Weber (2011)	Report
A supply chain view of product carbon footprints: results from the banana supply chain	Craig et al. (2013)	Working Paper
Product carbon footprint developments and gaps	Jensen (2012)	IJPDLM
Carbon-optimal and carbon-neutral supply chains	Caro et al. (2011)	Working paper
Input-output analysis and carbon footprinting: an overview of applications	Minx et al. (2009)	Economic Systems Research
Setting targets for reducing carbon emissions from logistics: current practice and guiding principles	McKinnon and Piecyk (2012)	Carbon Management
Product-level carbon auditing of supply chains: environmental imperative or wasteful distraction?	McKinnon (2010)	IJPDLM

(continued)

Table 3 (continued)

Title	Authors	Journal
Connecting the environmental activities of firms with the return on carbon	Oshika et al. (2012)	JoMA
Use of internal carbon price by companies as incentive and strategic planning tool	CDP (2013)	Report
Integrating information about the cost of carbon through activity-based costing	Tsai et al. (2012)	JCP
Making advances in carbon management. Best practice from the carbon information leaders	CDP and IBM (2008)	Report
Measuring carbon efficiency	Britt et al. (2011)	UCLA working paper
Managing carbon footprints in inventory management	Hua et al. (2011)	Int. J. Production Economics
Monitoring the carbon footprint of products: a methodological proposal	Scipioni et al. (2012)	JCP
Are there effective accounting ways to determining accurate accounting tools and methods to reporting emissions reduction?	Almihoub et al. (2013)	JSD
Drivers of tight carbon control	Bui and Truong (2013)	PMA Australasia Conference 2013 Proceedings
The role of input–output analysis for the screening of corporate carbon footprints	Huang et al. (2009)	Economic Systems
Corporate carbon performance indicators	Hoffmann and Busch (2008)	JIE
Measuring a carbon footprint and environmental practice: the case of Hyundai Motors Co. (HMC)	Lee and Cheong (2011)	Industrial Management & Data Systems

AAR Australian accounting review, *AAAJ* Accounting, Auditing and Accountability Journal, *AOS* Accounting, Organizations and Society, *EAR* European accounting review, *IJPDLM* International Journal of Physical Distribution and Logistics Management, *JCP* Journal of Cleaner Production, *JIE* Journal of Industrial Ecology, *JoMA* Journal of Management; *JSD* Journal of Sustainable Development, *UCLA* University of California, Los Angeles

taxonomic analysis can be described as building a set of categories that are organized on the basis of a single semantic relationship (Spradley 1997).

The analysis sought to identify what CMA practices have been documented in view of decision situations in which CMA information is used to inform decisions. The collected publications were therefore analysed based on their focus to identify dominant and under-represented decision situations supported by carbon information. The framework for this analysis was the CMA developed by Burritt et al. (2011) and presented in Sect. 2.

About two thirds of the sample of 31 publications were journal articles (23), whereas other publications comprised the remaining 8 articles (Table 3). Particularly notable is the observation that although most publications were

Table 4 Distribution of CMA literature by medium

Medium	Number of publications
AAAJ	3
JCP	6
Other journals	14
Grey literature	4
Non-academic literature	4
Total	**31**

published in accounting journals, apart from Accounting, Auditing and Accountabilit Journal (AAAJ) with three and the Journal of Cleaner Production (JCP) with six papers, each journal only features a single publication on the issue (Table 4).

4 Emission Management Merely a Means to an End

4.1 Diversity in Research and Practice

Despite the low number of identified publications, the analysis reveals a considerable diversity of CMA practices. Whereas only one of the reviewed publications explicitly considers the CMA framework presented earlier, a reference to its dimensions is made in virtually all of these publications. Nevertheless, only few publications discuss several of these dimensions (e.g. time frame of the information and generation routineness) at the same time (Table 4). Even fewer publications discuss a combination of the properties within one dimension (e.g. linking physical and monetary carbon information). The latter observation combined with the low overall number of publications does not allow a meaningful quantitative analysis of the collected data such as a correlation analysis (Neuman and Robson 2004). Hence, the following analysis draws on a qualitative analysis of the collected data, framed in the context of the EMA framework (Table 5).

The juxtaposition between monetary and physical carbon information was analysed in the researched publication sample. The number of publications focusing on physical carbon accounting was twice as high as the number of publications focusing on monetary aspects. Only four publications link the two dimensions and refer to the eco-efficiency concept (Sect. 5).

In these publications (e.g. Minx et al. 2009; Tsai et al. 2012), physical information is used to support the identification of relevant emission sources where potential for reduction is available. The advantages of physical information are emphasised particularly in situations where such information allows or requires acting regardless of the monetary implications of such actions (which may be negligible from a cost-benefit perspective, e.g. Bennett et al. 2013).

Table 5 Analysis of the publications in view of the CMA framework

Dimension	Property	Number of papers
Nature of the information	Physical	16
	Monetary	8
Time frame	Past	16
	Future	5
Length of time frame	Short-term	6
	Long-term	7
Routineness of information supply	Regular	7
	Ad hoc	15

The numbers in each dimension do not add up to 31 (number of publications) in each dimension since some publications do not identify an explicit decision situation

The literature that focuses on improving carbon performance has documented corporate interest on collecting and using physical information for purposes beyond the short-term (e.g. Engels 2009; Tsai et al. 2012; Lee 2012).

The low number of publications related to the monetary significance of carbon information could suggest that the benefit of using monetary carbon information is limited to a small number of decision situations and companies. Therefore, it can be expected that developments in this area are likely to be expected as monetary significance grows and (e.g. saving) potentials are explored more profoundly.

Last but not least, the observed lack of simultaneous attention to both the physical and the monetary dimensions of carbon information reveals a gap in the literature. Nevertheless, some co-occurrence of "monetary and short-term" and "physical and long-term" information was observed. This observation is further discussed in Sect. 5.

The time frame of carbon information—whether past or future-oriented—has been discussed from different views in the identified literature. A clear focus on past information was observed. This can be explained with the number of publications on carbon footprinting (e.g. Schmidt 2009; BIER 2011).

Six publications identify the advantages of using both past and future carbon information (e.g. Hua et al. 2011; Haigh and Shapiro 2012). For instance, building (future) emission scenarios are proposed as a subsequent action to estimating (past) emissions (Murthy and Parisi 2013).

Particularly prominent is the short-term/long-term dipole. Among the 31 publications, a focus on either type of information was not observed. Whereas about the same number of publications on short term (6, e.g. Green and Li 2012; Haigh and Shapiro 2012) and long term (7) carbon information was observed, 9 publications actually highlight the significance of both decision situations and the related information demand (e.g. Britt et al. 2011; Tsai et al. 2012). The focus on long-term information similarly assumes a high significance of carbon emissions on business operations, regardless of the ongoing political discussion.

Those publications that discuss carbon accounting in the context of long-term decisions (e.g. Haigh and Shapiro 2012) typically refer to the legitimising effects of carbon management. Such effects can also be achieved for organisations which do not emit considerable carbon emissions. Therefore, carbon accounting does not necessarily contribute in every case to reducing carbon emissions to the atmosphere but sometimes also help documenting that the company is not affected substantially by climate change issues.

In view of the fourth dimension of the carbon management accounting framework—regularity of data collection—the project-driven information collection dominated the sample (15). This emphasis is achieved due to the attention to carbon footprinting, which is often carried out on a one-off basis and requires detailed information to be collected specifically for a single project purpose. Jawjit et al. (2010) for example show that the ad hoc data collection in the case of greenhouse gas emissions from the rubber industry in Thailand allows for flexibility related to the goal of the analysis, its system boundary, and its functional unit (e.g. by including certain gases). Gielen et al. (2002), on the other hand, demonstrate a carbon emission reduction approach for a Japanese petrochemical company by means of information collected on a regular basis.

Only three publications identify situations in which information needs to be collected both on a regular basis and ad hoc.

4.2 Carbon Management Accounting—Emission Management or Emission Reduction?

The dominant features of CMA as documented in the literature sample indicate that CMA gravitates around management accounting rather than around carbon reduction accounting. In other words, carbon is seen as another resource or constraint; therefore it needs to be managed in order to safeguard the success of organisations. Managing carbon emissions, however, was revealed to not be limited to reducing emissions (which is the overarching purpose of carbon efforts in a national and supranational context). In fact, reducing carbon emissions (mitigation) is the less common argument discussed in the extant CMA literature (Table 6).

As the analysis reveals, extant research focuses carbon accounting attention on information generation for adapting to the changing environment. This is done for example to secure the legitimacy of the company (e.g. Pellegrino and Lodhia 2012; Sullivan and Gouldson 2012) or to estimate the future price of operations (e.g.

Table 6 Adaptation as the dominating motivation for CMA

Motivation	Adaptation	Mitigation	Both
Number of papers	20	4	3

Four publications do not make a clear statement as to the motivation for CMA

Cooper and Pearce 2011). Furthermore, carbon information related to corporate activities increasingly influences investment decisions (e.g. CDP 2013).

The above observation is in line with the previous observations pertaining to the CMA framework dimensions. The previously identified focus of publications referring to past information supports this view, as such information does apparently not focus on improving climate-related impacts. The under-represented monetary information demand—albeit seemingly counterintuitive—may in fact support the view that carbon is not perceived to be of considerable monetary importance for many researchers and companies, therefore it is not tracked, analysed and reported.

As the literature review reveals, extant research in the area of CMA assume that companies have largely used carbon management accounting for adapting to a changing and more constrained business environment without necessarily contributing to reducing their emissions. This finding largely reflects the assumptions and prepositions of the authors dealing with the topic and is in most cases not supported well with a balanced empirical analysis. Sustainable development and corporate sustainability require improvements with regard to carbon impacts. Research thus needs to develop more useful approaches to CMA which are empirically tested and can support corporate practices effectively.

The following section discusses how CMA can be developed to efficiently contribute to effectively reducing the total amount of emissions stemming from business activities.

5 Discussion

Summarizing the observations made in the previous section renders an important observation visible. CMA has been documented to be used *either* for producing an account of the carbon performance of a company (e.g. product carbon footprinting; typically in physical units) or, less frequently, for identifying important strategic and operational business issues (typically in monetary units). A connection between the two dimensions was observed in only 4 of the 31 papers (Burritt et al. 2011; Lee 2011; Britt et al. 2011; Hoffmann and Busch 2008). Yes, linking the two dimensions may enable a win-win situation, i.e. improving corporate financial performance by means of improved carbon performance (i.e. reducing carbon emissions). The following sub-section discusses implications for improving carbon efficiency.

5.1 Eco-efficiency Beyond an Improved Carbon Footprint

One particular challenge for accounting for eco-efficiency is that it cannot always be represented by hard data since a number of difficulties arise when attempting to measure it (Britt et al. 2011). This literature review reveals that the views and definitions of carbon efficiency may vary widely between companies. Furthermore, as discussed in Sect. 4, a benefit of carbon management may be gaining societal legitimacy or gaining power to influence future carbon legislation irrespective whether emissions are reduced or not. This assumption guides a number of publications that motivate carbon management with benefits other than improving product or process eco-efficiency. As a result, different representations of eco-efficiency have been discussed in the existing CMA literature.

Originally, eco-efficiency was defined as minimizing negative outputs while keeping or increasing economic success. In the case of carbon management, pricing of the environmental performance does not necessarily constitute a challenge. Typically all outputs can be in expressed monetary terms, and carbon emissions have market prices.

Eco-efficiency can also be applied in defining target outputs by the quantity produced from a given level of input. Carbon emissions, the undesirable output in this case, is mostly measured by the physical quantity that was generated, rather than attempting to monetize these factors (Färe et al. 1989). Examples of eco-efficiency indicators thus include value added (in monetary terms) per tonne of emitted CO_2 or the contribution margin of a product relative to its contribution to the greenhouse effect (in CO_2 equivalents).

A discussion of value creation in view of eco-efficiency has been virtually non-existent. Among the most prominent issues has been the lack of clarity when it comes to defining the constituents of eco-efficiency improvements through carbon emission reduction on one hand, or of creating carbon emission and eco-efficiency information on the other hand. As discussed in Sect. 2, (i) profit has been assumed as one motivation underpinning a given company's carbon management endeavours. In addition, (ii) credibility and leverage in climate policy development (iii) ethical considerations, (iv) fiduciary concern and (v) business opportunities have been discussed as motivation for managing carbon.

A closer inspection of these five motivations reveals a picture that carbon management accounting can create value and competitive advantages irrespective of whether carbon efficiency is improved or not. Profit or legitimacy can in some cases be boosted by offering products whose carbon footprint is known. This may provide some competitive advantage, at least until competitors offer similar information. A notable illustration of generating such a competitive advantage through superior carbon management accounting is DHL, who was the only company to offer a product whose carbon footprint could be established. Since competitors were not prepared to offer such information, DHL won a contract with the UK Government's Department of Health worth 2.3 billion Euro revenue over 10 years.

5.2 Implications for Developing Eco-Efficiency Indicators

The implications for the above discussion may influence the design of carbon management indicators. Whereas carbon indicators discussed in the existing CMA literature focus on physical benefits of reducing emissions (Wilson and Dowlatabadi 2007; Yang et al. 2009), the goal of improving corporate sustainability raises concern about developing more adequate carbon-efficiency indicators. Such indicators need to enable companies to create performance benchmarks in view of overarching objectives and to rethink carbon indicators from an eco-efficiency and corporate carbon management perspective.

Carbon performance from an eco-efficiency perspective can be measured by linking the economic (monetary) value created by carbon management activities with the (monetary) carbon management effort invested or the (physical) carbon emission reduction achieved. For example, the value created can be expressed as the ratio of market share increase due to carbon management to the resources invested in carbon management.

In summary, the future developments in measuring carbon efficiency should aim at providing a balanced set of environmental performance indicators that link overarching corporate objectives with carbon emission targets.

6 Conclusion and Outlook

Despite the multitude of publications emphasizing the sustainability relevance of carbon management and carbon accounting, the majority of the publications explicitly dealing with CMA discusses aspects not related to the management relevance of improved carbon performance. Most of the explicit CMA literature deals with past oriented and ad hoc information while focusing on decision support to secure legitimacy or profits. Sustainable development and corporate sustainability, however, would—in addition—require considering future-oriented decision situations and the generation of routinely generated carbon information to create continuous management attention and to support management decisions for improved carbon performance.

As the analysis conducted reveals, research in the area has mostly assumed and considered carbon accounting for the purpose of securing the success of the company rather than for emission reduction. While this assumption underlying a large part of the literature can also be observed in the general context of sustainability accounting (e.g. Bozzolan et al. 2013), our literature review may imply that pursuing one single perspective in an isolated manner could be too one-sided as neither the legitimacy based motivation of reducing carbon emissions nor the profit or cost oriented view may provide a sufficient incentive for carbon emission reduction, the broader introduction of CMA and the achievement of substantial carbon emission reductions.

The identified discrepancy between the motivations behind carbon accounting as assumed in many CMA publications—to increase profits and/or to secure legitimacy—and the sustainability objectives of carbon management—to reduce carbon emissions—supports the view that there is a considerable potential to develop CMA, particularly to better support future oriented management decisions and continued management attention leading to reduced carbon emissions and improved carbon efficiency. From a pragmatic perspective accounting and sustainability management researchers are challenged to propose and test new CMA approaches which effectively contribute to sustainable development and corporate sustainability by improving both corporate carbon and economic performance through carbon management accounting support and innovative CMA methods for better informed decisions.

Subsequent research is challenged to look into possibilities to harness the potential of CMA to actually reduce carbon emissions in view of an eminent ecological crisis (IPCC 2007). Expanding the currently limited set of carbon accounting tools at a management's disposal thus constitutes a central challenge.

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Corporate Sustainability Footprints—A Review of Current Practices

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Abstract This paper aims to contribute to the footprint debate by providing a systematic review of footprint concepts that can be used on the corporate or organizational level. This may take us one step further towards the conceptualization of lesser used footprints and their integration into sustainability management accounting. Based on the systematic review process seven different footprint concepts emerged that can be used at the organizational level (ecological, carbon, environmental, water, nitrogen, ethical and social footprints). These concepts are very diverse regarding scope and methodological explicitness, however, they offer an opportunity for organizations to tackle, monitor and communicate their sustainability performance on the organizational level. Five of the reviewed organizational footprint concepts are related to the environmental while two to the social domain of sustainability. As highlighted by the review, there seems to be no footprint concept going beyond one single dimension of sustainable development. This means that the interrelationships between the environmental, social and economic performance are not grasped by any of the introduced concepts, making them unsuitable for a comprehensive sustainability assessment. For this reason, integrating different corporate footprint concepts may be one important field of future research.

1 Introduction

Measuring our contribution towards sustainable development has been a focus of both policymaking and academia since the publishing of the Brundtland report (Brundtland 1987). Currently most approaches try to tackle sustainability by

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focusing on one or more of the environmental, social and economic domains, commonly referred to as the 'triple bottom line' (Elkington, 1998).

Beyond global or national level concepts and metrics—such as the OECD environmental performance measurement framework (OECD 1993), alternative welfare indicators like the ISEW (Daly and Cobb 1989), GPI (Cobb et al. 1995), the simpler HDI (UNDP 2004) or subjective welfare metrics in relation to sustainability, like the Happy Planet Index (HPI, Marks et al. 2006)—there is a wide range of research on measuring sustainability at the corporate level.

Corporate sustainability (Dyllick and Hockerts 2002; Salzmann et al. 2005) can be assessed by sustainability performance indicators (SPIs, Cunha Callado and Fensterseifer 2011; Ramos and Caeiro 2010; Searcy 2012; Bourlakis et al. 2014). While many different performance evaluation frameworks and concepts exist at the corporate level, this paper intends to contribute to the corporate management accounting literature by reviewing and conceptualizing the relatively specific field of corporate sustainability footprints.

Footprints are quantitative measurements trying to systematically quantify one or more dimensions of human impacts on sustainability (UNEP/SETAC 2009, De Benedetto and Klemes 2009), forming the 'footprint family' (Giljum et al. 2008 or Galli et al. 2012).

There are extensive reviews of numerous environmental, social and economic footprints (Cucek et al. 2012) and comparisons of the key members of the footprint family also exist (Fang et al. 2014), however, these studies do not address the organizational level. Corporate level footprint studies mainly focus on the most widespread footprint concepts such as the carbon footprint (e.g. Rugani et al. 2013). Therefore, it seems there is no clear picture on which footprint concepts are suitable for use at the corporate level.

This paper aims to contribute to the footprint debate by providing a systematic review (see Fink 1998; Tranfield et al. 2003) of literature on footprint concepts that can be used on the corporate or organizational level. Up to date no such (systematic) review has been prepared focusing on corporate level footprints, so this may take us one step further towards the conceptualization of lesser used footprints and their integration into sustainability management accounting.

This study is structured as follows: Sect. 2 provides terminology and the conceptual framework for the analysis of corporate footprints in the context of corporate sustainability and sustainability performance evaluation. Section 3 introduces the method of the systematic review process applied. Section 4 presents the results both in a descriptive and a thematic manner, while discussion of the results follows in Sect. 5. Suggestions and limitations are covered in the concluding section.

2 Corporate Sustainability Footprints—A Conceptual Framework

2.1 Measuring Sustainability Performance

It is possible to grasp sustainable development at many different levels (see for example Schaltegger and Csutora 2012). Whiteman et al. (2013) regard corporate sustainability as a company's activity in relationship to the planetary boundaries. From a more pragmatic perspective, corporate or organizational level sustainability can be understood as strategic and comprehensive management efforts to increase the economic, social and environmental capital base (Dyllick and Hockerts 2002; Salzmann et al. 2005; Schneider and Meins 2012) and thus improve corporate performance along the 'triple bottom line' (Elkington 1998). The emerging concept of corporate sustainability—regarded by some authors as a synonym of corporate social responsibility (CSR, van Marrewijk 2003)—resulted in different corporate guidelines on how to cover sustainability (see for example the EU Green Paper on CSR, COM 2001 or the UN Global Compact (2013) albeit without exactly specifying how to measure it.

While some argue that sustainability is a system level concept and cannot be understood within the boundaries of a company (e.g. Gray 2010) it is obvious that sustainable development cannot be achieved without the joint effort of all major groups of society. This, in turn requires that progress on all levels is continuously measured along the way and suitable metrics are developed for the purpose.

The scientific literature describing the efforts and results in the field of sustainability indicators has been continuously growing during the last decades. Questions remaining circle around the right set of indicators, the complexity and methodology of quantification and the reporting of results.

The Bellagio Principles developed by an international group of measurement practitioners and researchers as early as 1996 aimed at establishing principles to measure progress toward sustainable development. Ramos and Caeiro (2010) review the Bellaggio Principles and come to the conclusion that 'according to these principles, assessment of progress toward sustainable development should be guided by a clear vision of sustainable development and goals that define that vision. The assessment should reflect a holistic view of the linkage between social, environmental and economic considerations and it should have the appropriate scope while still offering a practical application' (Ramos and Caeiro 2010, p. 158).

Hardi and Zand, the developers of the original Bellagio Principles argue that the process of indicator development should be'open and inclusive' with effective communication and broad participation and it should be a continuous, iterative and adaptive process that provides ongoing support in the decision-making process (Hardi and Zand 1997).

Kuik and Verbruggen (1991) identify a number of criteria for operational indicators of sustainable development:

- the calculation procedure should be objective and scientifically sound;
- indicators should relate to clear policy objectives;
- indicators should have a clear interpretation and be understandable to non-scientists;
- indicators should cover the functioning of a system as a whole and
- indicators should be based on parameter values that are stable over a long period of time (Kuik and Verbruggen 1991 in: van den Bergh 1999).

When assessing a number of different evaluation methods of the environmental impacts of a certain economic sector, namely agriculture, van der Werf (2002) argues that the researcher has to identify which environmental problems are considered by the evaluation method, what types of indicators are used and what is the validity and feasibility of the method. Also, the trade-off between simplicity and complexity of the evaluation method should be considered (van der Werf 2002).

Corporate sustainability performance is measured by sustainability performance indicators (SPIs) (Cunha Callado and Fensterseifer 2011; Searcy 2012; Bourlakis et al. 2014). SPIs can be used at the action level (Herva et al. 2011) as tools to measure progress towards targets (Roca and Searcy 2012). Tahir and Darton (2010) group SPIs into two categories: resource efficiency measures how effectively natural, economic, human and social resources are converted, while fairness in benefit describes how fairly the benefits (or losses) of changes in the three domains are distributed amongst stakeholders of a certain activity. Sustainability performance can be measured at different levels relating to an organization: corporate, product, supply chain (see for example Bourlakis et al. 2014).

Keeble et al. (2003, p. 151.) argue that 'indicators should reflect the business realities, values and culture of the organization, and as such their development should not be constrained to prescribed methodologies or standards.' They also assert, however, that 'internationally recognized standards can play a role in informing the development of appropriate indicators'. According to their view, indicator sets should be balanced and should reflect the concerns of the stakeholders of the organization.

In order to facilitate the choice of indicators which meet the specific needs of an organization they suggest the use of 'screening' and 'ranking' criteria. Screening criteria help to identify indicators that meet the specific needs of the organization. According to the screening criteria corporate sustainability indicators should be able to measure progress over time; should be measurable and verifiable; relevant to key internal/external concerns; potentially benchmarkable; critically related to the core activities of the business and meaningful at the group level.

On the other hand, ranking criteria help the selection of indicators most appropriate for the organization. According to the ranking criteria corporate sustainability metrics should be leading rather than lagging; motivational; within the control of those accountable; practical to measure; likely to provide new, useful information; validated by engagement and help differentiate from competitors (Keeble et al. 2003).

Lagging indicators (outcome indicators or key performance indicators) refer to past performance and often do not provide enough information to facilitate decisions about future actions. In contrast with lagging indicators, leading indicators can foster a preventive approach to sustainability by providing information that helps respond to changing circumstances (Pojasek 2009). Leading indicators can help promote a positive culture and according to Pojasek (2009, p.89.) they 'should be (i) objective and easy to measure; (ii) relevant to the organization whose performance is being measured; (iii) able to provide immediate and reliable indications of the level of performance; (iv) cost-efficient in terms of information collection and (v) understood and "owned" by the group whose performance is being monitored'

Sustainability indicators may take various forms: they may be *absolute* or *relative* (BMU-UBA 1997), *past* or *future oriented*, *expressed in physical* or *monetary terms* (Burritt et al. 2011).

Indicators may refer to the *operation of the organization* only, or can be extended to at least a part of the *supply chain* that includes the given company (Schaltegger and Csutora 2012). Indicators can be quantified using a LCA-based *bottom-up approach* (collecting every single emission or other values related to a certain activity) or an *input-output approach,* where the mapping of direct and indirect material flows is following a top-down approach (Virtanen et al. 2011). *Hybrid approaches* mix bottom-up and top-down methods (Ozawa et al. 2013).

Based on the principles articulated in the literature a number of practical metrics have been developed to account for corporate sustainability performance, providing input to related organizational activities. Without attempting to provide a full account, some of the most widely used include:

- *Strategy implementation*: Sustainability Balanced Scorecards (SBSCs) offer companies a tool to integrate sustainability aspects into their strategic decision making process (Schaltegger and Dyllick 2002 or Epstein and Wisner 2001), while the eco-efficiency framework developed by the World Business Council for Sustainable Development (WBCSD 1996) measures the ratio of economic performance and environmental impacts with a set of indicators.
- *Process management*: indicators used within the frameworks of ISO 14031 (1998) or the German Ministry for Environment (BMU-UBA 1997) focus on the environmental domain, covering aspects like environmental load, environmental management or environmental condition.
- *Disclosure and reporting*: the Global Reporting Initiative (GRI 2002; Jasch and Lavicka 2006) provides guidance for companies to measure and communicate their environmental, social and economic performance. Organizations active in accounting standardization have also realized the importance of measuring and reporting sustainability performance (e.g. the International Accounting Standards Board, IASB, has published a recommendation regarding the principles and elements of management commentary, which is becoming more and more important for non-financial company information such as sustainability metrics (IASB 2010).

- *Rating*: sustainability indices provide industrial benchmarks for investors or other stakeholders, the Dow Jones Sustainability Indices (DJSI 2013) follow a best-in-class approach, meaning that companies can only be included and remain in the indices if they perform better than their peers along the different domains of corporate sustainability.

2.2 Corporate Footprint Concepts

Footprints are quantitative metrics addressing the natural resource use of humans (Hoekstra 2008) usually measured in terms of real or symbolic land area units, offering a demonstrative and easy-to-understand interpretation to these indicators (and thus chances for misinterpretation as well, see Lenzen 2006). Beyond natural resource use and area indicators, many other kinds of footprints exist—referred as the 'footprint family' by Giljum et al. 2008 or Galli et al. 2012—, trying to quantify one or more dimensions of human impacts on sustainability (UNEP/SETAC 2009; De Benedetto and Klemes 2009).

Footprints measured at the global or national level are more or less standardized, widely researched and used in practice. However, definitions and methodologies in the field of corporate (or organizational) level footprint indicators are surprisingly vague in some cases compared to the fast increase in the use of this concept recently. Corporate level footprints are single or multi-criteria full life-cycle based indicators describing the environmental or sustainability performance of business organizations providing goods and/or services (UNEP/SETAC 2009). Through the life cycle approach the different stages of the supply chain (raw material extraction, transportation, production, usage, waste management etc.) are taken into account. Corporate level footprints can be applied to other types of organizations as well, such as public bodies, non-governmental organizations (NGOs), etc.

In this paper corporate footprints are defined as systematic and structured metrics regarding any domains of sustainability in a life cycle concept. Recently the term 'footprint' has also gained popularity in a more general meaning as a buzzword (a synonym for 'impact') with no reference to the use of indicators. In this study, this meaning of 'footprints' is not considered.

Cucek et al. (2012) provide an extensive literature review of environmental, social, economic footprints by presenting numerous individual and composite footprint examples. Additionally, Fang et al. (2014) review and compare four key members of the footprint family (ecological, energy, carbon and water). Both studies offer a comprehensive analysis of their subject, however, they do not address the organizational level.

Rugani et al. (2013) analyze carbon footprinting methods in the wine sector, reviewing 35 life-cycle based studies in order to assess current practices of conceptualizing and measuring carbon footprints in the wine making industry.

This study gives a deep understanding of corporate carbon footprinting in one industry, but according to the best knowledge of the authors as yet there is no review aiming at assessing corporate footprint concepts in general.

2.3 Assessment Criteria

This article aims at providing a meta-analysis of footprint indicators aiming at the measurement of the sustainability performance of business organizations. According to Ramos and Caeiro (2010) a meta-evaluation is a 'critical assessment of the strengths and weaknesses of an evaluation, and draws conclusions about its overall utility, accuracy, validity, feasibility and propriety'.

For the purposes of this assessment of corporate sustainability footprints a set of criteria is proposed based on the literature presented above. The identified criteria have an internal (i.e. linked to internal organizational processes) or an external focus (i.e. linked to relationships with external stakeholders) and relate to the different steps of corporate performance evaluation (for example as described by the widely used ISO14031 international standard, see Jasch 2000).

The internal and external assessment criteria considered during this assessment are shown in Table 1.

System boundaries, scope of footprint concepts. The setting of system boundaries raises the question what impacts to take into consideration and what should be

Table 1 Suggested criteria for assessing corporate sustainability footprint concepts

Steps of performance evaluation	Criteria with an internal focus	Criteria with an external focus
Planning environmental performance evaluation:	System boundaries, scope of footprint concepts	Simplicity of interpretation,
– Selecting metrics		Validity (relationship to sustainability)
Developing and using data and information:	Simplicity and methodology of compilation	Usability for external communication
– Collecting data	Usability for internal communication	
– Analyzing and converting data		
– Assessing information		
– Reporting and communication		
Reviewing and improving environmental performance evaluation	Comparability across different time periods	Comparability across different organizations
	Control over factors determining performance	Potential for standardization
		Relationship to policy objectives

excluded from the analysis. If corporate footprints aim to provide an overview of the contribution to sustainability, not only direct but also indirect impacts should be covered.

Beyond the level of the whole organization, corporate footprints may focus on a product, a process or the whole supply chain (or a certain part of it) making the selection of system boundaries an issue during the design and calculation of the specific metrics. However, assessment of the indirect impacts is also the most challenging aspect of footprint calculations concerning methodology and data requirements.

Simplicity of interpretation. Simplicity of interpretation refers to the meaningfulness of the indicator to the different stakeholders receiving such information from a corporation. Often there is a trade-off between simplicity and the amount and quality of information carried by an indicator/set of indicators making the issue one of the most important to consider during the design phase. Corporate footprints may take the form of a single indicator or a set of indicators also influencing how easily stakeholders can interpret them.

Validity (relationship to sustainability). Validity, on the other hand, refers to whether a certain indicator brings us closer to understanding a corporation's sustainability performance. One question is, whether existing footprint indicators concentrate on only one single domain of sustainable development (i.e. the environment or society) or a certain part of these; or if they address the interrelationship between these domains as well (Kerekes 2011).

Another important issue is whether—similarly to their national or regional varieties—they are able to provide information regarding organizational performance in relation to sustainability (by considering the carrying or assimilative capacity of their environment).

Simplicity and methodology of compilation. The setting up and running of a sustainability performance evaluation system requires considerable time and resources. Footprint indicators, while trying to provide a simple to understand measure of corporate sustainability emerge as a result of complex data compilation and analysis processes.

Usability for internal and external communication. One of the most important purpose of developing sustainability metrics is communication towards internal and external stakeholders. The appeal of footprint indicators is based on their inherently expressive nature, which makes communication easier, although the amount of information communicated may be limited in some cases.

Comparability across different time periods. Measuring progress along the way to a more sustainable society is one of the most important purpose of sustainability metrics. Corporate footprints thus should be comparable across different time periods to inform decision makers about tendencies and to draw their attention to critical areas and potentials for improvement.

Control over factors determining performance. While it may be useful to observe indicators that fall beyond (or partially beyond) the control of an organization (e.g.

indicators relating to the state of the environment) the design and implementation of an indicator/set of indicators becomes more conducive if decision makers have the willingness and means to intervene in order to improve the situation characterized by the indicator.

Comparability across different organizations. In order to measure their progress towards a more sustainable operation, corporations should benchmark their activities with similar organizations of their own sector and other relevant industries. Apart from gaining useful insight into their own performance, such comparison is also important because it can become an important tool for internal or external communication.

Potential for standardization. There is extensive discussion on the need for standardizing indicators (see for example Roca and Searcy 2012). Standardization offers comparability over time and within the industry or economy (Young 1996), but it may also lead to information loss considering the different characteristics of organizations.

The clarity of the methodology used during the design and implementation of indicators is an important factor in designing useful metrics. Standardized performance measurement makes it possible to aggregate data at the industry and/or regional and national levels, which in turn helps policy making at these different levels. The use of indicators calculated on a voluntary basis may lack standardized content and procedures and thus lend themselves less well to such aggregation efforts. Regulatory bodies should consider the standardization of voluntary indicators so that they can benefit from their use.

In the case of footprints the most important challenge relating to standardization is the definition of organizational boundaries as noted earlier.

Relationship to policy objectives. Organizational footprints offer an opportunity for companies to tackle, monitor and communicate their impacts along the whole supply chain. If sustainability of the footprint can also be measured, authorities may have new tools to measure corporate performance and plan policies.

3 Method

This study is based on a systematic review of the literature (Fink, 1998; Tranfield et al. 2003; Klewitz and Hansen 2014). It differs from conventional or narrative reviews in that it aims to'synthetize research in a systematic, transparent and reproducible manner' (Tranfield et al. 2003).

The aim of using the systematic review method was to structure the research on the organizational footprint concepts and to cover the different concepts in organizational management accounting in a systematic way. A systematic review consists of both a descriptive, bibliographical analysis and a thematic analysis of the field (Tranfield et al. 2003).

The research process consisted of five steps as described as follows.

Step 1 *Collecting search terms:* The search terms (keywords) for the systematic analysis on corporate sustainability footprints were deduced from Sect. 2 and arranged into three clouds (see e.g. Klewitz and Hansen 2014), such as:

- '*corporate*' (including also company, enterprise, organization, firm[1]),
- '*sustainability*' (including also environmental, social, economic, responsible) and
- '*footprint*'.

Target publications needed to match one keyword per cloud at least, thus footprint concepts addressing at least one dimension of sustainability that can be used on the corporate or organizational level. In line with the objectives of this paper, the review does not aim to cover all records dealing with footprints or corporate sustainability management in general, only the intersection of the three clouds.

Step 2 *Scope of the review*: A systematic review can cover very different types of papers. To be able to manage the amount of records found and still maintaining quality, focus was put on peer-reviewed, academic papers in English language. Concerning the timeframe of the review, the analysis covered publications from 1992—when the concept of ecological footprint (Rees 1992) was developed—until 2013.

Step 3 *Data sources*: The systematic review covered the most important scientific databases (EBSCO, Emerald, ScienceDirect, Scopus, SpringerLink and Web of Science) that were appropriate to the interdisciplinary research field of this review (corporate sustainability management). Different databases applied different search syntax so search terms and search strings had to be adjusted accordingly. Based on the search terms a preliminary list (list C) of 2067 publications emerged. This number is large, as the search terms are common, and they are likely to occur somewhere in the full text of the records; but was sharply reduced by a title abstract and keyword analysis to 109 records (list B). The publications on list B were analyzed manually in-depth (abstract and full text) and a further 48 records were eliminated. The major reasons for eliminating articles from list B included (i) the use of the term 'footprint' in a very general sense and not as a performance evaluation tool, (ii) the focus was on the quantification of footprints with no focus on the use and applicability as a management accounting tool and (iii) where the keywords were present but not connected to each other at all. Additionally, 13 other publications found elsewhere and considered as important contributions to the field of research were manually added to the list by narrative inclusion. Thus, a

[1]In practice, much more keywords emerged, such as organisation, organisational, organization, organizational where strings—for example organi*atio*—were used depending on the syntax used by different research databases/engines (see step 3).

final list of 74 relevant publications emerged (list A) that are presented in the descriptive and thematic analysis. To improve the reliability of the analysis, three researchers (the co-authors of this paper) were involved in the research process.

Step 4 *Descriptive analysis*: a bibliographical analysis is provided on the occurrence of different footprint concepts, the temporal distribution of publications and journals covered by the records of list A.

Step 5 *Thematic analysis*: this step of the research aimed to identify the different corporate footprint concepts on an inductive basis emerging from the systematic review. The aim of this step was to systematically analyze the different concepts and analyze relationships.

The results of the systematic review are presented in the next section.

4 Results

The presentation of the results is structured in two subsections. First, a descriptive bibliographical analysis is provided to get an overview of the different organizational footprint concepts and their presence in academic literature. Then, a thematic analysis is provided on the organizational sustainability footprints uncovered by the systematic review, including their definition, applicability in organizational management accounting, scopes, system boundaries and data collection process.

4.1 Descriptive Analysis—Bibliographical Overview of the Literature

The 74 papers included in the review are distributed as follows. By footprint type (see Fig. 1), publications related to the carbon footprint found to be the most prevalent (35 papers). This is followed by the ecological (13) and the water footprint (8). The environmental footprint is the focus of 6 papers, the nitrogen (2), social (2) and ethical footprints (1) are the least used constructs; 7 papers discuss more footprint types. It should be noted that, as the review focuses on the application of the various footprints on the organizational level, papers not addressing this level were excluded from the review. The results therefore show that, although the concept of the ecological footprint predates carbon footprint, to date the latter has been more widely discussed on the organizational/company level.

Analysis according to publication date (Fig. 2) shows that, after initial studies from around the turn of the millennium, academic interest in the application of footprint type indicators in the assessment of organizational/corporate sustainability has increased markedly in the past 5–6 years. The largest number of publications (20 papers) are from 2012—it is too early to tell whether the reduction in 2013 represents a breaking point in the trend.

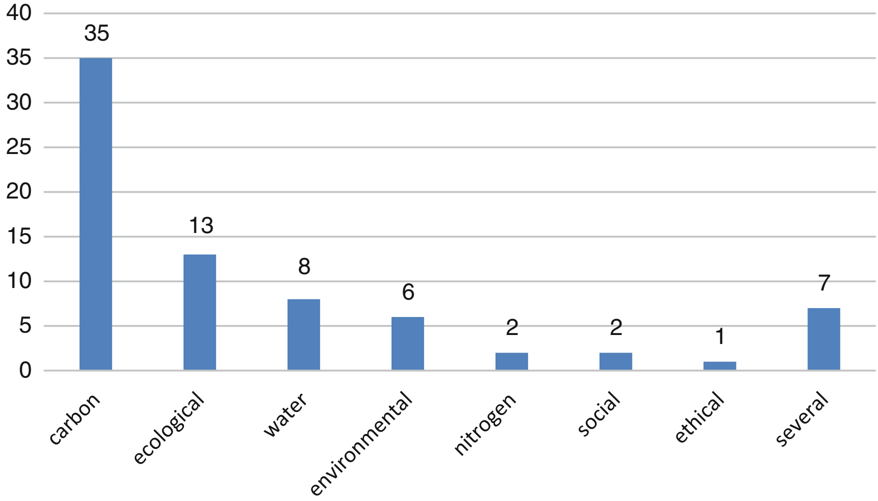

Fig. 1 Distribution of papers by footprint type

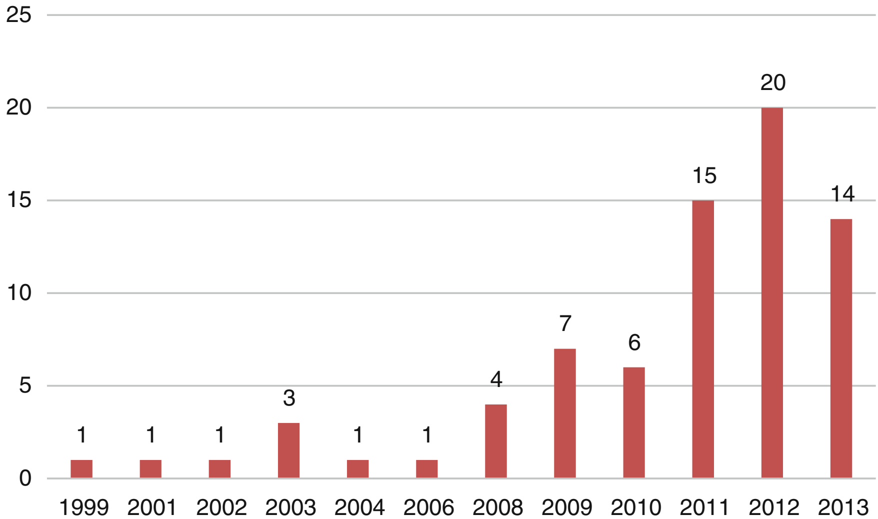

Fig. 2 Distribution of papers by year of publication

The distribution of papers by source can be seen in Table 2. The Journal of Cleaner Production stands out with 14 papers, followed by Ecological Indicators with 5 papers. 7 other journals contain 2–3 papers, and there is a large number of titles with 1 hit. This shows that the range of scientific journals dealing with

Table 2 Distribution of publications by source

Source	Number of publications
Journal of Cleaner Production	14
Ecological Indicators	5
European Business Review	3
Journal of Hazardous Materials	3
Journal of Industrial Ecology	3
Corporate Social Responsibility & Environmental Management	2
Environmental Science & Technology	2
Journal of Environmental Planning And Management	2
Sustainability	2
Other	38
Total	**74**

organizational footprint issues is very diverse—most of them are focusing on environmental management, but the topic has also made its way to journals without a primary focus on sustainability.

4.2 Thematic Analysis—Types of Corporate Level Footprint Concepts

Different corporate footprint concepts are structured in this section on an inductive basis emerging from the systematic review introduced earlier. The presentation of seven different concepts in this subsection follows the order of their occurrence in the literature (see Fig. 1): carbon footprint, ecological footprint, water footprint, environmental footprint, nitrogen footprint, social footprint and ethical footprint. At the end of this subsection a comparison of the different footprints is provided according to the aspects of organizational sustainability they cover.

4.2.1 Carbon Footprint

Parallel to the increasing concern about climate change also in the corporate sphere, many companies and other organizations tend to account and control their carbon emissions. The Carbon Footprint (CF) measures the total amount of greenhouse gas (GHG) emissions that are directly and indirectly caused by an activity (Wiedmann et al. 2009; Jungbluth et al. 2012) or are accumulated over the life stages of a product (Galli et al. 2012). Organizational CF in this sense can be approached as the amount of carbon or GHG emissions that are directly or indirectly caused by the organization's processes or emerge over the full life-cycle of the products or services of this organization (Jensen 2012; Townsend and Barrett 2013).

CF may only refer to CO_2 only or to a further set of GHGs. CCAR (2008) and OPEN:EU (2010) consider six different GHG groups (covered by the Kyoto Protocol), such as carbon-dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6). In this latter case the name of CF is somewhat misleading as other non carbon-based GHGs are covered as well. In this sense Greenhouse Gas Footprint (GHGF), suggested by Downie and Stubbs (2013); Northey et al. (2013) or even Global Warming Potential Footprint (GWPF) see for instance Meisterling et al. (2009) or Svensson and Wagner (2011a) may be a more appropriate term to use.

CF is usually expressed in terms of mass units (g, kg or t) of CO_2 (WBCSD/WRI 2004; Vázquez-Rowe et al. 2013). If further GHG-emissions are covered as well, CO_2-equivalents are calculated (Panela et al. 2009).

CF is also used as an element of the Ecological Footprint (see for example Wackernagel et al. 1999). In this case CF is measured in land units. However, when converting emissions into land areas based on the carbon uptake capacity of ecosystems, a variety of assumptions are applied, which increases uncertainty (Galli et al. 2012). For this reason, mass units (kgs or tons) are preferred on the organizational level.

Different protocols provide reasonably exact methodology for calculating CF. A European Commission review (2010) considers 11 methodologies and 11 implementation policies as more or less appropriate for accounting carbon emissions.

On the organizational level, carbon emissions are usually grouped into different 'scopes' or 'tiers'. The Greenhouse Gas Protocol (WBCSD/WRI 2004) protocol suggests three different scopes:

- *Scope 1*: *Direct GHG emissions* including sources that are owned or controlled by the company (e.g. emissions from own boilers, vehicles etc.)
- *Scope 2*: *Electricity indirect GHG emissions* from the generation of purchased electricity consumed by the company. (The protocol considers here solely electricity, but other purchased energy—heat or steam—should also be considered here.)
- *Scope 3*: *Other indirect GHG emissions* based on activities such as external transportation or the use of sold products. Scope 3 is an optional accounting category that allows for the inclusion of all other indirect emissions. The Scope 3 standard of the GHG Protocol (WBCSD/WRI 2011) provides detailed guidance for organizations how to include their carbon impacts along the value chain. Beyond upstream emissions, Lenzen and Murray (2010) stress the importance of covering downstream impacts in organizational carbon footprint accounts as well.

Although Scope 3 emissions account for a significant part of organizational emissions (Stein and Khare 2009 or Downie and Stubbs 2012), indirect CF elements (other than Scopes 1 or 2) are usually underestimated by companies. Matthews et al. (2008) claim that only 14 % of the total CF is covered by Scope 1 and only 26 % by Scopes 1 and 2 among US companies. However, Matthews et al.

(2008) consider Scope 3 as too vaguely defined and suggest instead Scope 3 (indirect emissions for production) and Scope 4 (indirect emissions for the total life cycle including delivery, use, and end-of-life).

The WBCSD/WRI protocol also sets as a minimum requirement that companies should separately account for and report on scopes 1 and 2 (WBCSD/WRI, 2004).

Measurement of the organizational CF is usually happening based on the LCA approach as suggested by the GHG Protocol, (WBCSD/WRI 2004, 2011), but it can also be accounted based on an environmentally extended input-output analysis (EEIOA) see e.g. (Cagiao 2011, Townsend and Barrett 2013) or a hybrid approach by combining the two (Chakraborty and Roy 2012).

In corporate carbon footprint accounts, the question of system boundaries is an important issue. Focus can be put on the organizational (Høgevold 2011; Elmualim et al. 2012), product (Baldo et al. 2009), process (Chakraborty and Roy 2012, Caro et al. 2013) or supply chain (Lee and Cheong 2011; Babin and Nicholson 2011; Lee 2011) level, or a combination of the above (Lenzen and Murray 2010, Carballo-Panela et al. 2012).

For accounting the carbon emissions within different system boundaries related to organizational activity, standardization is an important issue (Diaz et al. 2012; Caro et al. 2013), and compared to other organizational footprint concepts, standards like the GHG Protocol (WBCSD/WRI 2004, 2011) foster the process of applying common practices in corporate carbon accounting.

In this context carbon footprinting is considered as a management accounting tool, but it can also be used for other purposes, such as product labelling, improving eco-efficiency or reporting (Baldo et al. 2009; Velásquez et al. 2009; Pattara et al. 2012; Trappey et al. 2012).

4.2.2 Ecological Footprint

The Ecological Footprint (EF) in general tracks the human demand for, and compares it against nature's supply of biocapacity (Rees 1992; GFN 2012; Csutora and Zsoka 2014, Toth and Szigeti 2016). The EF originally measures human pressure onto the ecosystem in terms of global hectares regarding the following fields (for a detailed methodology see GFN 2005; Mozner et al. 2012' Borucke et al. 2013; Kocsis 2014): cropland, grazing land, fishing grounds, forests, carbon uptaking areas,[2] built-up land.

On an organizational level, EF means the land area necessary to cover resource consumption and waste generation of an organization (Maltin and Starke 2002), an accounting tool to measure biological capacity needed to support organizational activity (Holland 2003).

Unlike the other footprint concepts covered in this analysis, corporate EF is expressed in area units (Herva et al. 2011; Diaz et al. 2012), in most cases in global

[2]This element of EF is also called carbon footprint. However, it is not the same as the Carbon Footprint discussed earlier (which is expressed in mass units—kg or t).

hectares (Bagliani and Martini 2012). Lenzen (2003) differentiates four categories of organizational land use: consumed, degraded, replaced and disturbed areas.

Contrary to EF on the global or national level, where, as mentioned earlier, the components are more or less commonly accepted, the concept of organizational EF lacks a widely accepted framework and methodology. Beyond the core resource use components (GFN 2005, 2012), further elements are covered by some authors, such as wastes (Herva et al. 2008; Bagliani and Martini 2012), water (Gondran 2012; Herva et al. 2012) or pollutants and toxic wastes (Herva et al. 2010). Although there are some attempts to include the impacts of pollution, corporate EF remains rather a metrics of resource use. Furthermore, it does not include risks and uncertainties (Holland 2003).

The scope of EF in the organizational accounting system can be the organization itself (Maltin and Starke 2002; Lenzen 2003), its products (Kitzes et al. 2009) or can be extended to the supply chain (van Hoek 1999). The organizational EF can also be regarded as the combination of individual product footprints. Kitzes et al. (2009) stresses the need for carefully and explicitly defining system boundaries and thus the scope of the analysis (products, processes etc.). It should also be indicated whether the analysis is based on mutually-exclusive EFs of different organizations (that can be summed) or the different organizational EFs overlap with each other. For quantifying organizational EF—similarly to the calculation of organizational CF—there are both LCA- and IO-based approaches (Lencen 2003; Herva and Roca 2013).

As it can be seen, corporate EF is not a standardized tool as there is no common practice on what to include in it, but it provides aggregated information for the organizational management accounting system. Beyond an internal management accounting tool (Holland 2003) that can also be linked with ABC-accounting (Bagliani and Martini 2012), it can be used for strategic planning and decision making (Gondran 2012), reporting and communication.

On a global or national level EF can be regarded as an absolute sustainability indicator (compared to the available biocapacity). On the organizational level, however, available biocapacity is not defined (Herva et al. 2011).

4.2.3 Water Footprint

The water footprint (WF) evolved from attempts to capture the flow of 'virtual water' between nations embodied in traded products (Allan 1998; Hoekstra and Hung 2002; Marjaine Szerenyi and Kocsis 2012). It measures the amount of freshwater used to produce the goods and services consumed by the individual or community or produced by the business (Hoekstra et al. 2011). The WF is normally expressed in terms of water volume (litres or cubic meter) and is composed of three elements: the 'blue WF' referring to the consumption of surface and groundwater (this does not include non-consumptive water use, where the water withdrawn is returned to the source); the 'green WF' referring to the consumption of rainwater (insofar as it does not become runoff); and the 'grey WF' which measures water pollution, defined as the amount of water necessary to dilute pollution to the levels required by ambient water quality standards (however, insufficient standards—or the lack of such standards—may make this definition somewhat problematic). A widely accepted methodology for the calculation of the WF is provided in the Water Footprint Assessment Manual published by the Water Footprint Network (Hoekstra et al. 2011).

For a company, the WF can be measured as the sum of the WFs of the products delivered by the company and the 'overhead', referring to water use which cannot be attributed to particular products (e.g. water use in cleaning, toilets, kitchens etc.). (Hoekstra et al. 2011) To this date, several companies—mainly from the food and beverage sector—have published studies on their water footprint, including Coca-Cola (2011), SABMiller (2010), Dole Food Company (Sikirica 2011), Unilever (2013) and Finnish wood, paper and bioenergy company UPM (2011).

Regarding the system boundaries, there is broad consensus that organizational WF should include indirect (supply chain) water consumption—indeed, existing studies indicate that this component (especially where agricultural inputs are used) is typically much larger than the direct component of the WF (e.g. Coca-Cola 2011; Ene et al. 2013; Lambooy 2011, Ruini et al. 2013). The studies are more diverse when it comes to the inclusion of water consumption associated with the use phase of the company's products. This is usually not calculated, except in cases where it is likely to be important. For example, Ruini et al. (2013) include the water used for cooking in their study on the WF of Barilla pasta, and in case of Unilever (2013), the use of their cleaning and personal care products is found to be the most important component of the company's WF. In general, it is the recommendation of the WF's creators that factors which are expected to play a minor role (i.e. contribute less than 10 % to the overall WF) can be excluded. Hence, it is recommended that energy and transport should only be included in the analysis if it involves the use of hydropower or biomass. The water use related to labor (water and food consumption etc.) should be excluded to prevent double accounting (as these water uses will normally be included in the water footprint of workers as consumers). (Gerbens-Leenes and Hoekstra 2008; Hoekstra et al. 2011)

Significant obstacles related to the use of the WF for the measurement of corporate sustainability include the difficulty to obtain data from the supply chain as well as issues related to the interpretation of the results. While the former problems are being addressed by improving databases, e.g. the WaterStat database provided by the Water Footprint Network which includes data on various crops taking into account soil and climate conditions in locations across the globe), the latter issues have led some to call into question the usefulness of the WF as a whole (Chapagain and Tickner 2012). At the core of the interpretation difficulties lies the fact that—opposed to other footprint-type measures, notably the CF—in case of the WF, the geographical dimension (such as water scarcity and overall pressure on the given water system) plays a crucial role. In practice this means that the WF itself does not provide information about the potential environmental damage associated with the water use—indeed, a smaller WF may be less sustainable than a larger one, depending on where the water is sourced (Riddout and Pfister 2010). The recommendation for sustainability assessment put forward by the Water Footprint Assessment Manual (Hoekstra et al. 2011) is that the WF of a process is unsustainable if it occurs at a time and place where the overall WF is considered unsustainable; and/or if it can be reduced at an acceptable social cost.

In order to address the problem of interpretation and comparability arising from geographical differences, weighted WFs have been created using water stress factors to standardize footprint components from different locations (Riddout and Pfister 2010). However, according to Chapagain and Tickner (2012), such weighted WFs are also problematic because they fail to take into account temporal variability in water availability, as well as the socio-economic context (such as the opportunity costs of water use) which may also affect the sustainability of WFs.

Consequently, Chapagain and Tickner (2012) emphasize that great care needs to be taken when interpreting WF data, and the focus of organizations should be on addressing the adverse impacts of WF rather than simply aiming for its reduction. They describe the WF as a powerful communication tool with important awareness-raising potential, but stress the need to avoid overly simplistic applications such as volumetric WF labelling schemes for consumer goods. In a business context, they see the main value of WF as a tool to assess strategic risks related to water and to create motivation to address these risks. The WF may also help to foster communication and cooperation between different stakeholders relying on the same water base.

4.2.4 Environmental Footprint

While organizational EF aimed to provide compact information on some selected aspects of environmental sustainability, the organizational environmental footprint (EnvF) intends to provide a multidimensional environmental assessment (Gaussin et al. 2013) covering the full scope of environmental impacts of organizational activity (Northey et al. 2013).

In the Europe 2020 Strategy—'Roadmap to a Resource Efficient Europe' (COM 2011)—organizational EnvF is described as a multi-criteria indicator for measuring the environmental performance of organizations as a management accounting tool. EnvF follows a life-cycle approach and its main aim is to decrease negative environmental impacts concerning organizational activities, taking into account the whole supply chain (from raw material extraction to waste management). Organizations may be businesses, non-profit organizations or public bodies (COM 2013a).

The organizational EnvF can be calculated by accounting resource and waste flows crossing organizational boundaries. Different sources cover different elements of EnvF, but a common characteristic is that they are all multidimensional metrics. Organizational boundaries for calculating EnvF are set to cover all facilities and associated processes that are owned or operated by the organization. The environmental impacts that emerge within the organizational boundaries are defined as direct impacts. Indirect impacts are impacts emerging upstream or downstream along the supply chains linked to organizational activities, but falling outside of the organizational boundaries.[3] GHG offsets are not included in EnvF.

Product-level EnvF covers the environmental impacts of products or services of the organization (Gaussin et al. 2013; COM 2013b). Theoretically the sum of product EnvFs accounts for the total organizational EnvF for a certain period.

Although Pearce and Miller (2006) uses corporate EnvF and EF as synonyms, in this analysis they are clearly differentiated as EnvF is a multidimensional metric and aims to cover all environmental aspects of organizational activity. The quantification of EnvF can add further information to the organizational management accounting systems. Laurent et al. (2012) found that organizational EnvFs do not necessarily correlate with CFs.

As a similar concept, corporate E-footprint (Earth-footprint, EarthF) is a company's impact on Earth's life- and ecosystems (Svensson and Wagner 2012) measured by the material and energy flows impacting them (Svensson and Wagner 2011b). As EarthF is a very analogous concept to EnvF, it is regarded as a synonym in this analysis.

4.2.5 Nitrogen Footprint

One of the newest members of the 'footprint family' is the nitrogen footprint (NF), developed by Leach et al. (2012). Release of reactive nitrogen to the environment caused by human activity results in a series of disruptive effects including smog, acidification, eutrophication and increase of the greenhouse effect. The authors emphasize that the magnitude of human disruption to the nitrogen-cycle is actually much greater than in the case of carbon: anthropogenic release of nitrogen is approximately double the amount resulting from natural processes, while for CO_2 emissions it is only 5–10 %. This means that there is a great need for tools to better track and communicate our impacts on the nitrogen cycle.

The NF was first developed at the level of individuals and defined as the total amount of N (expressed in weight units) that is released to the environment due to an individual's consumption of food and energy (including the indirect impacts such as the energy needed to produce goods consumed). The method of calculation is based on country level average per capita data, which was used to calculate the

[3]The EU framework (COM 2013a) provides a reasonably exact method for calculating the 14 default EnvF impact categories using indicators with natural measurement units in the fields of: climate change, ozone depletion, ecotoxicity–freshwater, human toxicity–cancer effects, human toxicity–noncancer effects, particulate matter/respiratory inorganics, ionizing radiation–human health effects, photochemical ozone formation, acidification, eutrophication–terrestrial, eutrophication–aquatic, resource depletion–water, resource depletion–mineral/fossil, land use. It is possible to narrow the scope of indicators with proper reason or there is also an option for including further indicators.

total NF of two countries: the United States and the Netherlands; as well as to create an individual NF calculator, where the average amounts are scaled up or down depending on lifestyle factors (Leach et al. 2012). As a next step, Leach et al. (2013) have developed the methodology to calculate NF on the organizational level and applied it for the University of Virginia (to date, this is the only organizational NF assessment). The methodology includes the calculation of direct impacts as well as upstream components (the amount of N associated with the production of energy and food consumed at the University), and can potentially be applied across a wide range of other organizations.

4.2.6 Social Footprint

Together with the increasing interest in various environmental footprints, ideas have also been put forward to express the social aspect of sustainability through similar indicators. However, most of these are at an early stage of operationalization and are little more than metaphors at present. One such attempt which is specifically intended to assess the social sustainability performance of organizations is the social footprint (SF) developed by McElroy et al. (2008). Rooted in the capital-based understanding of sustainability, the SF measures organizational impacts on human, social and constructed capital compared to previously defined standards. Contrary to environmental footprints, the impacts measured here are positive ones, that is, how much an organization contributes to producing its share of social capital. The greatest difficulty with this approach is to determine the level of social capital production that can be considered sustainable, and to determine the contribution of the organization.

McElroy et al. (2008) use the example of the UN millennium development goals (United Nations 2000)—such as the eradication of extreme poverty or the promotion of gender equality—for which the UN has set partial quantitative targets for 2015 and has drawn up the necessary budgets for their achievement. These budgets can be broken down to a national and then a personal level, and compared to the financial contributions (per employee) that a company makes to the UN (which includes any direct payments as well as indirect contribution through taxes paid and partially forwarded to the UN by the national governments). Based on this example one may question the validity of the approach proposed by the creators of the SP, as payments to the UN are hardly the best way to assess a company's contribution to the eradication of poverty or to gender equality—providing employment and fair wages, or equal treatment of women may clearly be more important but cannot be captured in this model. It is also clear that there are many forms of social capital and organizational contributions to the creation of this capital—for all of these, a different kind of SF would need to be calculated. Therefore, in its current form, the SF cannot be considered as an indicator. Rather, it is a concept for creating indicators along similar lines.

4.2.7 Ethical Footprint

Similarly to SF footprint, corporate ethical footprint (EthF) is also an emerging concept, covering mainly the social aspects of corporate sustainability performance. Although it lacks a methodological rigor compared to the different environmental footprint concepts, Baden and Harwood (2013) highlights its importance to provide a normative, positive sounding and easily understandable framework for accounting social aspects of a company. Beyond the scope of academic discussion, the concept of EthF also emerges in the NGO field (Ethical Footprint, 2010).

4.2.8 Comparison of the Different Footprint Concepts

Different footprints presented in the thematic analysis cover different dimensions of the sustainability performance of companies and other organizations. Figure 3 aims to provide an overview of the relationship of the different concepts.

As the systematic analysis shows, footprint concepts are mostly related to the environmental domain of sustainability. EnvFs cover the broadest domain, with a multidimensional metrics, they can provide information on virtually all environmentally related aspects of an organization. EnvFs use natural measurement units in the different fields.

The further footprint concepts in the environmental field provide only a partial coverage of the organizational environmental aspects, thus deliver compact input to the management accounting system on some selected key areas. Corporate EF originally focused on resource use and carbon emissions resulting from energy use.

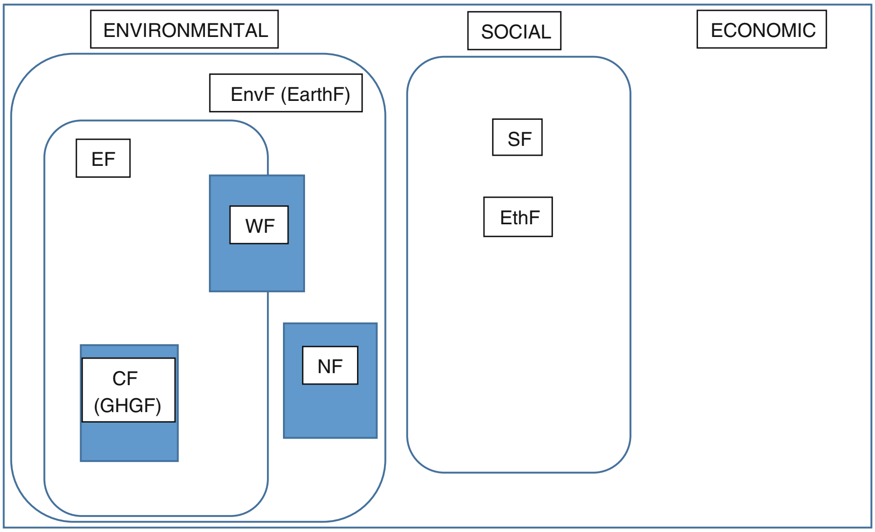

Fig. 3 Relationship of the different corporate sustainability footprint concepts

Although there are many attempts to include other output aspects (wastes or even other emissions), organizational EFs usually cover a much narrower area than EnvFs, but provide results in aggregate measurement units of ghas.

The further corporate footprints in the environmental domain provide information on a specific field in natural measurement units. CF (and GHGF) provide detailed information on organizational carbon emissions. CF is also included in EF accounts, although in the latter case emissions are converted to area units. The systematic review showed attempts to include WF into the EF accounts, but this was not a general practice. The review did not show any evidence on the coverage of NF within organizational EFs, although it is an important element of EnvF.

Regarding the social domain of sustainability, SF and EthF are attempts to cover the contribution of an organization to the social capital in a systematic way. Although a multidimensional metrics is suggested in the literature, it is much less operationalized compared to footprints in the environmental domain.

Based on the present review, no evidence of organizational economic footprints emerged. Of course, the notion is widely used, but rather as a buzzword and in an ad hoc sense (see elimination criteria in the method section), not as a concept to systemize the organizational impacts in a structured way.

Further discussion on the different footprint concepts follows in the next section.

5 Discussion

In this section the different organizational footprints are discussed according to the assessment criteria presented in subsection 2.3.

System boundaries, scope of footprints. In theory, all of the different organizational footprints cover both direct and indirect impacts of the organization. For example in the field of CF methodologies three different layers of impacts can be quantified: Scope 1 covers direct emissions, Scope 2 relates to emissions emerging from purchased energy and Scope 3 concerns all other indirect emissions, such as production of purchased materials or transportation by external vehicles. The inclusion of indirect impacts is the area where footprint indicators can provide valuable additional information to assess organizational sustainability over simple resource use or pollution data. In case of the WF or CF for example, a company's direct water consumption or CO_2 emissions can be measured without footprint calculations, but will not include important portions of the company's overall impact in these areas.

Beyond the general consensus that indirect impacts should be included in footprint calculations, the precise setting of the boundaries of the analysis remains a key issue. For example, upstream impacts are considered more often, while there is a greater variation regarding the inclusion of downstream impacts. Another open question is whether personal impacts generated by internal stakeholders (employees, managers, owners etc.) should be included in corporate footprint accounts (and if yes, to what extent—considering also the principle of additionality). Furthermore, the practical difficulty of assessment of the indirect impacts concerning methodology and data requirements often leads to the omission of these impacts, especially in the case of CF and EF. In WF and NF accounts, however, the inclusion of supply chain impacts is standard.

The building blocks of organizational footprints are typically product and process level footprints. In some cases, accounting and reporting focuses mainly on the footprint of the company's products rather than the whole organization itself (for example in case of CF or WF).

Validity (*measurement of sustainability*). This aspect refers to the issue whether footprints provide a comprehensive and relevant picture of the contribution of organizations to sustainability.

One point is the coverage of the concepts. As it was summarized by Fig. 3, most footprints address the environmental field, but there are differences in the range of impacts they cover, with EnvF being the broadest, followed by EF, while others—CF, WF, NF—address specific areas. SF and EthF relate to the social dimension of sustainability. There are currently no footprint concepts addressing different dimensions of sustainability simultaneously.

Another important aspect is whether the footprints are suitable for measuring organizational sustainability in the area they address. In case of CF, EF and EnvF, a higher footprint indicates higher impact, but there is no clear benchmark on whether a certain level of the footprints can be considered sustainable (compare for example to national or global EF where the respective biocapacity sets a basis of the assessment of sustainability). However, in case of the WF, the importance of the spatial and temporal dimension (considering local and seasonal water scarcity) means that there is not even a clear link between the size of the footprint and its impacts. Although not addressed in existing publications, this problem may also affect the NF (the same amounts of N can have different impacts in different environments).

In case of SF and EthF there is an attempt to compare the indicator to an external standard but in this case the validity of the indicator itself is questionable.

Simplicity of compilation, methodology of quantification, standardization. In general, it can be noted that the comprehensive and rigorous quantification of organizational footprints is a complex and time consuming exercise with substantial data requirements. The calculation of CF and WF is more or less standardized. The most important future challenge is the definition of organizational boundaries. EF and CF are fairly well standardized as a global or national concept but on the organizational level it is not yet clear enough what to include. There are different frameworks for EnvF even though it aims to cover all relevant environmental aspects of an organization. The methodology put forward for the NF is relatively clear, but as it is in an early stage of development, practical applications are as yet limited. SF and EthF are rather concepts than exact indicators, thus are not appropriate to provide standardized outcomes in their current formats.

The method of data collection is another important point. The bottom-up or LCA-based approach—trying to take every single impact into account—is usually used for accounting the direct impacts or summing the different product-level footprints in order to calculate the organizational footprint. The top down or IO-based approach—using certain standard emission factors or input-output matrix-based methodologies—are mainly applied for calculating indirect impacts.

Simplicity of interpretation and usability for internal and external communication. Some of the reviewed footprints—CF, WF, NF or even the EF—can be measured with one single and easy-to-communicate indicator (with further sub-indicators). Others—EnvF, SF and EthF—consist of a set of indicators, for example EnvF provides comprehensive and detailed information on organizational environmental performance but cannot be communicated and interpreted easily.

The simplicity of single indicator footprints create a good chance for easy communication and provide good opportunities for raising awareness among non-expert audiences ('out-of-the-box' communication). However, this feature may also lead to oversimplified or misleading interpretation. Multi indicator footprints, such as EnvF may provide a more complex perspective on sustainability performance but their interpretation and communication may be challenging.

Control over factors determining performance. Organizations usually have higher control on direct impacts compared to indirect ones emerging somewhere else along the supply chain—this applies to all footprint concepts covered in this review. Supply chain impacts may also be influenced by setting supplier requirements or by procurement decisions (upstream), and informing customers or product design (downstream). However, such improvements may not always be reflected in the calculated footprint values, due to methodological issues (e.g. resource savings by a specific supplier may not be reflected in the CF, WF, NF and EF if upstream data are collected by an IO method.)

Comparability across different time periods and organizations. Footprints provide a good framework for temporal comparison at a certain organization. If the method of footprinting is well defined, data for different periods may reflect actual organizational progress towards sustainability. Of course, comparisons on a relative basis (taking into account changes in turnover, size etc.) may provide more meaningful information.

This latter aspect also arises when attempting to compare different organizations, as they have very diverse characteristics. Comparisons within industrial sectors or industry specific benchmarks would be the most useful information to one organization's management accounting. However, in practice this is scarce due to the lack of application of the footprint concepts in organizational accounting, different methods of calculation and the lack of information on peer companies. An exception may be CF, where there is an increasing trend regarding calculating and publishing organizational footprints. Product level comparisons may play an even more important role in the future in case of CF, WF (especially in agriculture, food industry), NF and EF.

Relationship to policy objectives. Areas covered by sustainability footprints may strongly overlap with policy focus. In this case, footprint information from organizational accounts may demonstrate commitment and progress along policy objectives. For example, the disclosure and management of organizational CFs are in line with national climate strategies or in case of the availability of corporate or product level WFs, river basin authorities may have better information on organizational water consumption patterns. However, the lack of officially accepted methodologies currently makes it impossible to create national accounts or to regulate companies based on organizational footprints.

6 Conclusions

This paper intended to contribute to the footprint discussion by providing a systematic review of footprint concepts as management accounting tools that can be used on the corporate or organizational level. To achieve this goal, a systematic review has been performed to provide an overview of the organizational footprints. According to the best knowledge of the authors, no previous systematic review exists focusing on organizational sustainability footprints. This paper may therefore take the scientific discussion one step further to the conceptualization of less used footprints and their integration into sustainability management accounting.

The review was focusing on peer-reviewed academic publications in English by using scientific databases, but was also supplemented with some other records based on a narrative inclusion. A possible limitation is that not all related publications were covered with such a method, however, the transparent, structured and reproducible manner of the systematic review intended to increase reliability of the process.

Based on the systematic review process seven different footprint concepts emerged that can be used at the organizational level. These concepts are very diverse regarding their scopes and methodological explicitness. A common feature is that they offer an opportunity for companies and other organizations to tackle, monitor and communicate their sustainability performance on the organizational level. As these concepts may provide information on direct as well as indirect impacts, they may play a key role as organizational sustainability performance metrics.

Five of the reviewed organizational footprint concepts emerged during the systematic review are related to the environmental domain of sustainability, while two (substantially less developed) concepts cover the social aspects. An interesting point highlighted by the review is that there seems to be no footprint concept going beyond one single dimension of sustainable development. This means that the interrelationships between the environmental, social and economic performance of the corporations are not grasped by any of the introduced indicators making them unsuitable for a comprehensive sustainability assessment. For this reason, integrating different corporate footprint concepts may be one important field of future research.

This paper focused on the analysis of different organizational level footprint concepts and not exact indicators. A further direction for future analysis might be to broaden and deepen the scope of the comparison to address exact calculation methods for quantifying the different types of organizational footprints.

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Carbon Accounting: A Review of the Existing Models, Principles and Practical Applications

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Abstract The Kyoto Protocol has opened up an international debate about the appearance of different regulations which focus on carbon accounting and reporting. Specifically, the Kyoto Protocol established that the Conference of the Parties shall define the relevant principles, models, rules and guidelines, in particular for verification, reporting and accountability for carbon allowances. As a consequence, many companies remain confused as to the appropriate carbon accounting model. Due to the existing controversies on the topic, the aim of the present work is twofold. Firstly, and from a macroeconomic point of view, this work attempts to analyse the different carbon accounting regulations existing at the international level. Secondly, and from a firm level, describe the main practical carbon accounting principles and applications in different industries. Main results reveal the existence of different approaches at the corporate level in the international context about carbon accounting and reporting. This has several implications from a company point of view, being one of the most important the impact of the carbon accounting model choice on companies' financial performance.

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1 Introduction

The significant increase in the emission of greenhouse gas (GHG), especially carbon dioxide (CO_2), to the atmosphere has dramatically given rise its temperature. In 1997, to deal with this problem the Kyoto Protocol (KP) which is an international agreement linked to the United Nations Framework Convention on Climate Change (UNFCCC) was signed. This protocol aimed at lowering GHG emissions and redistributing the costs associated with climate change policy, by moving them from citizens of less developed countries, that are not producers of GHG emissions, to the companies which are the true responsible for the emissions and, moreover, they get profits from them. Nevertheless, climate change international agreements, such as the KP, mainly focus on quantitative targets which are generally focused on computing GHG emissions in each country (Ascui and Lovell 2012). The KP has been ratified by different countries/regions among them the European Union (EU) which will have to adapt to the new regulations contained in the KP as well as those developed in the EU and in other specific countries. However, some of the 120 countries committed to the KP in its first phase, such as Japan, Canada and New Zealand, have announced that they will not continue under the KP scope during its second phase (up to 2020). This announcement seems to be a serious problem because of the committed countries/regions to the second phase of the KP, such as the EU, Australia and Norway, only represent about 15 % of the total GHG emissions worldwide. It is worth mentioning that EEUU did not sign the first phase of the KP and will continue with this attitude in its second phase.

Examining the KP leads us to deduce, among others, some relevant aspects included within it and which are the following: (a) all parties shall formulate, implement, publish and regularly update national and regional programs including measures to mitigate and to facilitate an adequate adaptation to climate change; (b) these programs involve economics sectors such as energy, transport, agriculture, forestry and waste management; and, finally, (c) the Conference of the Parties shall define the relevant principles, models, rules and guidelines for reporting, verification and accountability of carbon allowances. At this point, Schaltegger and Csutora (2012) consider that “carbon accounting has played a crucial role on the scientific and political level to inform societal and political institutions and to support decision-makers in designing regulations and international agreements”. Due to the growing importance of this topic on political, societal and company-specific dimensions, this work aims to contribute to the existing literature in several ways. First, from a macroeconomic point of view, a complete review of the different regulations related with carbon accounting and reporting at an international level is provided. Secondly, we examine the annual reports of different international companies belonging to different industries in order to show the different principles and practical applications of the different carbon accounting models. The results obtained show that many companies remain mislead about the appropriate carbon accounting model proposed by different organisations such as: (a) the International Financial Reporting Interpretation Committee (IFRIC) of the International Accounting

Standard Board (IASB); (b) the Financial Accounting Standards Board (FASB) in the United States (US); and (c) other national-focused regulations. Considering that there is currently no globally accepted regulation or a best practices code related with carbon accounting, it is deemed important to analyse the way that companies account and report on that issue. Thus, the implications of this work will not only help companies, shareholders and other stakeholders about the impact of the carbon accounting model on firms' financial performance but also for regulators to continue get a consensus about the most appropriate model of carbon accounting.

The rest of the work is organised as follows. In the next section general features of the KP are studied. In Sect. 3 the carbon accounting principles and the proposals of international institutions and those provided by previous research are analysed. Section 4 focuses on analysing several carbon accounting practical applications of companies operating in different industries is provided. This will allow obtaining an overview of the practical considerations regarding carbon accounting worldwide. Finally, the last section comprises the main conclusions and highlights the implications of the research.

2 Kyoto Protocol: Main Features

Although the KP was approved on 11 December, 1997, when the industrialized countries promised to put into effect a set of measures to reduce GHG emissions, it did not go into force until 16 February 2005. The KP was gradually ratified with the exception of the most important country in the world economy: the US. The non-commitment of the US with the KP was motivated by the following reasons: (a) the KP did not include the participation of developing countries; and, (b) the costs of compliance would damage the US economy (Hoffman 2005). Ocaña (2003) indicates that the refusal of the US to ratify the KP has meant a sharp decline in the price of carbon allowances and therefore an equivalent reduction in costs for the committed economies. This can be explained by the fact that the US would have been one of the main buyers of carbon allowances, since it is the main world polluter (Ocaña 2003). Under the KP, countries should, individually or jointly, ensure that their aggregate anthropogenic CO_2 emissions do not exceed their assigned amounts, calculated pursuant to their quantified emission limitation and reduction commitments, with the objective to reducing their overall emissions by at least 5 % below 1990 levels in the commitment period 2008–2012 (McKenzie 2009). The KP establishes that some countries will have to reduce their emissions and others might be able to increase their emissions targets in the 2008–2012 period. According to the KP, countries will have a certain degree of flexibility in how they make and measure their emissions reductions. In particular, an international emissions trading regime will be established allowing industrialized countries to buy and sell carbon allowances amongst themselves. They will also be able to acquire emission reduction units by financing certain kinds of projects in other developed countries through a mechanism known as Joint Implementation. In addition, a Clean Development Mechanism will enable industrialized countries to finance emissions-reduction projects in developing countries and receive credit for doing so (European Commission 2005). Other interesting feature of the KP refer that all parties shall formulate, implement, publish and regularly update national and regional programmes containing measures to mitigate climate change and measures to facilitate adequate adaptation to climate change. These programs would concern the energy, transport, industry, agriculture, forestry and waste management industries.

It is worth mentioning that 194 countries approved in 2012 at the UNFCCC in Doha a deferral of the KP commitment period until 2020. However, some countries such as Japan, Russia, Canada and New Zealand decided not to continue under the KP scope during this phase. Another interesting feature of this phase of the KP is that the carbon allowances allocation procedure introduces some important changes (European Commission 2013). In a first stage, the carbon allowances are allocated to the obligated plant operators. This initial allocation will be valid for temporary trade periods. While within the first two trading periods (2005–2007 and 2008–2012) carbon allowances were allocated mostly for free, in some industries such as power production, there will be no free allocation any more. Definitely, these new rules have important consequences on carbon allowances accounting methods to be applied.

3 Carbon Accounting

One of the aspects that still must be solved is how companies should account for carbon allowances in their financial reports. In fact, the lack of an internationally accepted regulation about carbon accounting has motivated the appearance of some national-focused initiatives.

However, this situation seems not to be an acceptable scheme if we think that the impact of GHG emissions is of a global nature. In this section we focus firstly on analysing the accounting principles on which carbon allowances accounting are based, and secondly on the accounting models proposed at the international level by the Federal Energy Regulatory

Commission (FERC), the FASB, the IASB and the Resolution 8 February 2006 of the Spanish Accounting Standard Setting Board (ICAC) in Spain.

3.1 Carbon Accounting Principles

The generally accepted accounting principles (GAAP) try to ensure that the information supplied by firms regarding carbon allowances should present fairly relevant information. Thus, the World Business Council for Sustainable Development (WBCSD 2003, pp. 23–24) has released a series of principles that are derived in part from accepted financial accounting and reporting principles. Specifically, these are relevance, completeness, consistency, transparency, accuracy and conservativeness.

According to the **relevance principle**, the quantification and reporting of carbon allowances should include only information that users need for their decision-making. Data, methods, criteria and assumptions that are misleading or that do not conform to project protocol requirements are not relevant and should not be included.

The **completeness principle** considers all relevant information that may affect the accounting and quantification of carbon allowances meets all requirements. This means that all the carbon allowances effects of a project should be considered and assessed, all relevant technologies or practices should be considered as baseline candidates and all requirements within relevant chapters should be completed to quantify and report carbon allowances.

Consistency requires that methods and procedures are always applied to carbon allowances and their components in the same manner and the same criteria and assumptions are used to evaluate significance and relevance, and that any data collected and reported will be compatible enough to allow meaningful comparisons over time.

Transparency is critical for quantifying carbon allowances, and the information should be compiled, analysed and documented clearly and coherently, so that reviewers may evaluate its credibility. A transparent report will provide a clear understanding of all assessments, supporting GHG emissions reduction accounting and quantification. This should be supported by comprehensive documentation of any underlying evidence to confirm and substantiate the data, methods, criteria and assumptions used.

Accuracy will generally ensure greater credibility for carbon allowances and reduce uncertainties as far as practical. Greater accuracy will generally ensure greater credibility for any GHG emissions reduction claim.

Conservativeness refers to the use of conservative assumptions, values and procedures when uncertainty is high; accordingly, these conservative values and assumptions are those that are more likely to underestimate than overestimate GHG emissions reductions.

3.2 Carbon Accounting Approaches

This section focus on analysing different carbon allowances accounting models proposed by several authors and by different international institutions. This should be useful because of there is not an international agreement on a normative approach to for carbon allowances accounting and reporting. This review will allow obtaining an up to date and global overview about the carbon allowances accounting approaches. Likewise, this section also focus on highlighting and further discussing some specific aspects of emission trading programs such as impairment, cost allocation, allowances that have been previously analyzed in the field (Johnston et al. 2008; Burritt and Schaltegger 2010; Ebrahim 2013).

3.2.1 Proposals from International Institutions

The FASB considers that most firms account for carbon allowances in a similar way to regulations of Federal Regulatory Energy Commission (FERC) in the US. FERC requires firms to recognize carbon allowances on an historical cost basis. However, some companies follow an intangible asset model for carbon allowances. Thus, in relation to what carbon allowance represents, Engels (2009) poses the following question: "Does an allowance represent an expense or an asset?" The FASB is aware of diversity in practice and proposes three alternatives for carbon allowances accounting: (1) the characteristics of carbon allowances and the nature of the asset are delimited; (2) more extensive, which could include different aspects such as asset recognition, measurement and impairment, revenue recognition, cost allocation, liability recognition, presentation and disclosure; and, (3) consisting of not issuing any guidelines on the carbon allowances accounting for the moment.

The proponents of alternative (1) consider that "guidance on the nature of carbon allowances would eliminate diversity in practice and improve comparability of financial statements" (FASB 2007, p. 3). The proponents of alternative (2) consider that diversity in accounting for carbon allowances can only be eliminated if all aspects of emission trading programs are addressed, with the need to add a series of aspects such as: initial measurement and recognition, gain recognition and deferral, impact of the reporting entity's intended use, measurement and recognition of purchased allowances, related parties, impairment, expense recognition and costing methods, classification, presentation, disclosures and liability recognition and measurement. The proponents of alternative (3) observe that guidance issued by the FASB could create convergence issues that might need to be addressed in the future when the IASB resumes work on its emissions project (FASB 2007, p. 4).

Another proposal is that developed by the International Financial Reporting Interpretation Committee (IFRIC) of the IASB. The IASB issued its first draft interpretation (D1), called Emission Rights, about the accounting for carbon allowances. Under the D1, companies should account for the carbon allowances received from governments as intangible assets, and recorded initially at fair value (Cook 2009). GHG emissions would then give rise to a liability for the obligation to deliver carbon allowances to cover those emissions. The IFRIC and IASB tried to eliminate the risk that divergent accounting practices will develop in this new area. The main proposals of D1 are:

- Carbon allowances are intangible assets that should be recognised in the financial statements in accordance with the IAS 38.

- When carbon allowances are allocated to a participant by a government (or government agency) for less than their fair value, the difference between the amount paid and their fair value is a government grant that is accounted for under the IAS 20.
- As a participant emits pollutants, it recognises a provision for its obligation to deliver allowances or pay a penalty in accordance with IAS 37. This provision is normally measured at the market value of the allowances needed to settle it (IASB 2004).

This initial proposal made in 2003 by the IFRIC (which in 2004 became known as IFRIC 3) has been further analysed by different international bodies such as: the Institute of Chartered Accountants in England and Wales, the Accounting Standards Board of Japan, the Canadian Institute of Chartered Accountants, the Conseil National de la Comptabilité (France), and the European Financial Reporting Advisory Group (EFRAG), among others. Comments were mainly concerned on relevance and fair representation of economic reality.

After analysing all the comments made by the different bodies, the IASB decided to withdraw IFRIC 3 at its June 2005 meeting. Although the IFRIC 3 was not finally approved, we can refer broadly through an example to certain proposals made on the accounting process of the carbon allowances because they are of high interest at the international level. Furthermore, it will allow bettering explaining some aspects analyzed in this work. To that aim, the carbon accounting structure model proposed by Ratnatunga et al. (2011) is used.

- Example: Company "EMC" is a participant in an emissions trading scheme. On the first day of the period 2008 the company is allocated free of charge allowances for the year to emit 20,000 tonnes of CO_2. The market price of the allowances on that day is 10 € per tonne.

Company "EMC" recognises the allocation of allowances at their fair value or market price (20,000 tonnes at 10 € per tonne):

Accounting entries	Dr	Cr
Allowances (intangible assets)	200,000	
Deferred income		200,000

At the end of the year, company "EMC" measures its carbon allowances for the year at 30,000 tonnes. On the last day of the year, it buys 10,000 carbon allowances to cover the emissions in excess of the initially received. The market price of carbon allowances at the end of the year is 9 € per tonne. Based on IAS 36 there should be some testing for impairment, since, the fair value is 9 now overall 180,000.

– The company recognises the purchase of the additional allowances at 9€ per tonne.

Accounting entries	Dr	Cr
Allowances (intangible assets)	90,000	
Cash		90,000

To conclude, the recent progress made by the accounting standard setters is not complete. Both FASB and IASB "tentatively" decided that purchased and allocated allowances should be recognized as assets. Moreover, a liability exists when the allowances are allocated because the definition of a liability is met. The obligating event in this case is the allocation of allowances. However a very long road lies ahead of the official accounting bodies as they plan to discuss a vast number of questions starting with the issues of measurement and presentation (including netting) and whether a right to future allocations can be recognized as an asset.

Therefore, the issue of carbon allowances accounting is still on the IASB current agenda. Nonetheless, the EFRAG is currently working on the accounting standardization of carbon allowances based on a paper issued by French Standard Setter Autorité des Normes Comptables (ANC 2012) 'Accounting of GHG Emissions Rights Reflecting Companies' Business Models,' which is intended to inspire the international debate and, as soon as possible, the development of an international accounting standard by the IASB. Furthermore, the EFRAG (2013) issued a comment paper to discuss recognition and measurement of carbon allowances and liabilities under an Emission Trading Scheme (ETS) with the view to stimulate debate in Europe and beyond.

In the absence of authoritative guidance by the IASB, several approaches have developed that IFRS preparers apply to account for the effects of ETS. A survey by PriceWaterhouseCoopers (PwC) and the International Emissions Trading Association (IETA) (2007) identified as many as fifteen variations to account for the effects of EU ETS. Table 1 highlights three main approaches[1] chosen from the initial fifteen because of their better applicability for the companies such as suggested by Sergiyenco (2010).

The issue of how to manage carbon allowances in accounting is also a concern in Spain, and in this sense the ICAC, the most important body issuing accounting regulations in that country, released in 2006 a Resolution to establish general norms for the recognition, valuation, and information to be supplied in the financial annual reports concerning carbon allowances. In 2002, the ICAC also released a previous Resolution which makes Spanish firms to develop and disclose an environmental report in the annual financial statements. The 2006 Resolution indicated that carbon allowances must be accounted in the balance sheet as an intangible asset, giving rise to the corresponding entry of the income to be distributed over several associated

[1]There is evidence that the largest European emitters primarily rely on Approach 3 (see Table 1).

Table 1 Carbon accounting approaches in practice

	Approach 1	Approach 2	Approach 3
Initial recognition—*Allocated* allowances	Recognise and measure at **market value** at date of issue; corresponding entry to government grant	Recognise and measure at **market value** at date of issue; corresponding entry to government grant	Recognise and measure at cost, which for granted offsets is **equal to zero**
Initial recognition—*Purchased* allowances	Recognise and measure at **cost**	Recognise and measure at **cost**	Recognise and measure at **cost**
Subsequent treatment of allowances	Allowances are subsequently measured at **cost or market value**, subject to review for impairment	Allowances are subsequently measured at **cost or market value**, subject to review for impairment	Allowances are subsequently measured at **cost**, subject to review for impairment
Subsequent treatment of government grant	Government grant **amortised** on a systematic and rational basis **over compliance period**	Government grant **amortised** on a systematic and rational basis **over compliance period**	Not applicable
Recognition of liability	Recognise liability when incurred (i.e. when emissions are produced)	Recognise liability when incurred (i.e., when emissions are produced)	Recognise liability when incurred (i.e., when emissions are produced). However, the way in which the liability is measured (see below) means that often no liability is shown in the statement of financial position until emissions produced exceed the offsets allocated to the participant
Measurement of liability	Liability is measured based on the **market value** of allowances at each period end that would be required to cover actual emissions, regardless of whether the offsets are on hand or would be purchased from the market	Liability is measured based on: the **carrying amount** of **offsets on hand** at each period end to be used to cover actual emissions (i.e. market value at date of recognition if cost model is used; market value at date of revaluation if revaluation model is used) on either a FIFO or weighted average	Liability is measured based on: the **carrying amount** of **offsets on hand** at each period end to be used to cover actual emissions (nil or cost) on a FIFO or weighted average basis; *plus* the **market value** of offsets at each period end that would be required to cover any **excess emissions**

(continued)

Table 1 (continued)

	Approach 1	Approach 2	Approach 3
		basis; *plus* the **market value** of offsets at each period end that would be required to cover any **excess emissions** (i.e., actual emissions in excess of offsets on hand)	(i.e., actual emissions in excess of offsets on hand)

Source PriceWaterhouseCoopers (PwC) and the International Emissions Trading Association (IETA) (2007)

accounting periods, under the consideration that the transfer of carbon allowances to firms without a balancing entry is equivalent to a government subsidy to companies. The valuation proposed is that of the general principle of the purchase price. Moreover, considering that this intangible asset is not subject to a process of systematic depreciation, its non-depreciable nature is established. According to this Resolution, carbon allowances must figure among the intangible assets with the creation of a specific account called "GHG emission rights". They are initially recognised at cost (purchase or production), and then after recognition they should be assessed either at cost-subject to impairment.

A very important issue is that the different ETS in several countries have resulted in the appearance of different approaches to regulate carbon allowances, which has led to potential differences in their accountability. For example, the French Standard Setter Autorité des Normes Comptables (ANC 2012) in France released the report: "Accounting of GHG Emissions Rights Reflecting Companies' Business Models," which is intended to inspire the international debate and, as soon as possible, the development of an international accounting standard by the IASB. Furthermore, EFRAG (2013) issued a comment paper to discuss recognition and measurement of carbon allowances and liabilities under an ETS with the aim of stimulating the debate in Europe and beyond. Specifically, French regulation about carbon accounting model consider carbon allowances as assets (resources controlled as a result of past events and from which future economic benefits are expected to flow to the entity). With respect to the measurement of carbon allowances at cost is appropriate for companies which are forced to buy carbon allowances owing to their manufacturing activity. However, it does not accurately reflect the risks taken by using carbon allowances as a market instrument. On the contrary, measurement of carbon allowances at market value is appropriate within a financial approach, but it induces unjustified volatility for companies which are forced to buy carbon allowances. Others issues to be considered of this regulation refer to buying carbon allowances before/after GHG emissions.

After the appearance of French regulation on carbon accounting, the EFRAG (2013) in collaboration with some international institutions has tried to further clarify and explain some important aspects regarding carbon accounting, being the most relevant: (a) free allocations should be initially recognized at fair value at the date they are received by the entity, with the credit being posted to deferred income or other comprehensive income; (b) a liability and a production cost should be recognized as the entity produces emissions; (c) carbon allowances held and the liability should be presented separately, and the liability should be further recognized when the allowances are surrendered to the authority; and, (d) the 'own use' exemption is granted for derivatives entered for compliance purposes in accordance with IAS 39 requirements.

3.2.2 Proposals from Different Authors

This section focus on reviewing the main works in the field of carbon accounting to identify the main models applied in practice. It is worth mentioning that although carbon accounting and reporting has gained more relevance during the last ten years, we focus on a complete overview including earlier works. This will allow bettering understanding the efforts made and gained steps in this field since its origins. Furthermore, this issue is important if we think that to the most of our knowledge, there is no a broad review on the topic in the academic literature. It is further interesting to consider a complete scope of the existing works in the field if we think that there is no an international agreement about the most appropriate carbon accounting model, an issue that makes this field completely different from other accounting issues such as provisions, income taxes, intangibles, assets regulated by some IFRS. This is of special importance when we think in a similar way that Deegan (2008), who indicated that new accounting standards will help financial users as well as employees to analyze the carbon credit as a net position or gross position.

A concise review of existing carbon accounting standards and necessary treatments were suggested by Ewer et al. (1992). Based on the accounting standards of FASB the authors proposed and discussed positive and negative aspects of the three approaches. That is, considering carbon allowances as: (a) inventories; (b) marketable securities; or, (c) intangibles. They also reinforced that carbon allowances should be measured at their fair value for internal planning and control purposes, whereas for external needs they supported the historical cost valuation model.

Wambsganss and Sanford (1996) proposed another model of carbon accounting. These authors recommended that carbon allowances should be treated as donated assets, which are valued at market price when received, with a "corresponding increase in contributed capital". They suggested that the book value of the allowances to be considered as a part of the cost of production, when they are used to compensate for pollution. Finally, they proposed that such treatment allows recognition of the allowances, which helps in more effective estimation of the cost of pollution in the financial statements.

In a more recent work, Schaltegger and Burritt (2000) opened a discussion of proposed methods of carbon accounting with a review of current practices by international standard setters. They concluded that the most popular view was advocated to be the intangible asset treatment model. Starbatty (2010), representing IASB, provides a brief description of the joint project on ETS (between IASB and FASB) as well as discusses the scope of the current IASB's ETS's project.

Other authors have also indicated concerns associated with IFRIC3. Cook (2009) outlines the discussions and debates about carbon accounting that take place among the IASB. Those discussions are still ongoing, pointing to both the politics and lobbying that surround the issue as well as the conceptual and technical issues involved. At the same time, MacKenzie (2009) also concentrates on the official recommendation and its failure, attributing the opposition of businesses to the fact that companies oppose accounting treatments that increase earnings volatility and IFRIC 3 was perceived to be a serious threat. Bebbington and Larrinaga-Gonzalez (2008) consider the view of the standard setters on "the valuation of granted allowances" and further decline the interpretation.

Meanwhile, several academics emphasized practical aspects of carbon accounting. Engels (2009) surveyed a number of companies across Europe on the question of whether and how they account for participation in carbon markets. The results of the survey showed that even though a relatively high number of surveyed businesses have employed different approaches to set question, there is "…a level of ignorance among some of the companies showing that they have *not* used the Phase 1 of the EU-ETS to develop a perspective".

Johnston et al. (2008) found that the market assigns a positive value to carbon allowances interpreting this positive reaction as an anticipation of asset recognition. In addition, they report positive reaction associated with carbon allowances purchase, interpreting that as information release over risk management.

Zhang-Debreceny et al. (2009) argue that problems related to the IASB actions are associated to the complicated nature of carbon allowances—so it is an unprecedented issue for the accountants. The traditional accounting, according to the authors, of assigning asset/liability status can only worsen the situation with GHG abatement.

Finally, Burritt et al. (2011, p. 80) indicate that "accounting for carbon management can be seen as an approach and as a set of new information management and accounting methods that aim to create and provide high quality information to support a corporation in its movement at least towards carbon neutrality".

4 Practical Applications of Carbon Accounting

Considering that there is currently no regulation or a best practices code related to carbon accounting, it is deemed important to analyse the way that companies report on that issue. This section focuses on analysing how companies of different industries and countries account for carbon allowances. To do that, we selected companies from different countries worldwide (developed countries: the USA, Australia, Canada and the EU, etc., and developing countries: China, India, Brazil, Mexico, etc.), and sought to represent both countries that have not ratified, approved, adhered to or accepted the KP, and countries that have. Firms from the USA belong to the former situation, while organizations from Canada, Europe, Australia, China, India, etc., have evolved towards the latter situation. The activity sectors selected are consistent with those established in the *Green Paper on Greenhouse Gas Emissions Trading* within the EU (Commission of the European Communities 2000) and in the KP (i.e. Aerospace and Defence; Airlines; Chemicals; Energy; Forest and Paper Products; Industrial and Farm Equipment; Metals; Mining, Crude-Oil Production; Motor Vehicles and Parts; Petroleum Refining and Utilities). These sectors are considered as the most sensitive to GHG emissions and therefore are those that should consider the importance to somehow reflect the carbon allowances in their financial annual reports.

Following the structure proposed by Ratnatunga et al. (2011), we first analyzed the financial annual reports of the companies belonging to the specified industries to deduce how carbon allowances are accounted for. It is interesting to note that some companies belonging to specific industries do not present this information in their financial annual reports. Due to that issue, we finally selected those industries which comprise the companies disclosing this type of information in a more complete manner. Specifically, we focus on petroleum, utilities, energy and metal industries.

4.1 Petroleum Industry

After examining some leading petroleum firms form an international perspective we can deduce the following principles related with carbon accounting:

- Carbon allowances granted free of charge are accounted for at zero carrying amount.
- Liabilities resulting from potential differences between available quotas and quotas to be delivered at the end of the compliance period are accounted as liabilities and measured at their fair market value.
- Spot market transactions are recognized as an income at their cost.
- Forward transactions are recognized at their fair market value on the face of the balance sheet.
- Changes in the fair value of such forward transactions are recognized as an income.

It is worth mentioning that other firms comprised in the petroleum industry consider carbon allowances as an intangible asset and they are measured at acquisition cost.

- Allowances received for no consideration under the National Emission Allowance Assignment Plan, are initially recognised at the market price prevailing at the beginning of the year in which they are issued, and a balancing item is recognised as a grant for the same amount under deferred income, which is charged against income as the corresponding tons of CO_2 are consumed.

- These allowances are not depreciated as their book value equals the residual value and, therefore, their depreciable basis is zero, as they keep their value until delivery; meanwhile they may be sold at anytime. Carbon allowances are subject to an annual analysis on impairment. The market value of the allowances is measured according to the average price of the stock market of the EU carbon allowances provided by the European Climate Exchange (ECX).
- As the emissions are released into the atmosphere, the company records an expense on the heading "Other operating Expenses" in the consolidated income statement acknowledging a provision whose amount is based on the CO_2 tones emitted, measured, (i) at book value, (ii) or by the quotation price at the closing when the firm analysed does not have enough emission allowances available for the period.
- When carbon allowances for the CO_2 tons emitted are delivered to the authorities, the intangible assets as well as their corresponding provision are derecognised from the balance sheet without any effect on the income statement.
- CO_2 emitted by the companies' industrial plants and the "CO_2 emission licences" attributed to it under the National CO_2 Licence Allotment Plan do not give rise to any financial statement recognition provided that: (a) it is not estimated that there will probably be a need for costs to be incurred by the company to acquire emission licences in the market, which would be recognised by the recording of a provision; or, (b) such licences are not sold in the event that they are excessive, in which case income would be recognised.
- The companies have not recognised in its financial statements the possible valuation or devaluation of these licences. If they acquire or sell licences it will record them. However, if an insufficiency of licences occurs the appropriate provisions will be recorded, if that becomes appropriate.
- The licences allocated are for less than the volume of CO_2 emitted for a quantity considered to be insignificant for purposes of the financial statements. The licences allocated to the company exceed the volume of CO_2 emitted and so no provision was recorded for the year.

4.2 Utilities Industry

After the corresponding analysis, it seems that utilities companies follow 4 different carbon accounting approaches that lead us to define the following practical applications:

First approach:

- Carbon allowances are recorded as an intangible asset within current assets and are initially recorded at cost and subsequently at the lower of cost and net realisable value.

- For allocations of carbon allowances granted by the relevant authorities, cost is deemed to be equal to the fair value at the date of allocation.
- Receipts of such grants are treated as deferred income and are recognised in the income statement over the period to which they relate.
- A provision is recorded in respect of the obligation to deliver carbon allowances and charges are recognised in the income statement in the period in which CO_2 emissions are made.
- Income from carbon allowances which are sold is reported as part of other operating income.

Second approach:

- GHG emission quotas appear in the section for other intangible assets together with research and development expenses.
- Emission quotas purchased are recorded as intangible assets at acquisition cost.
- When the carbon allowances have been granted for zero they are not shown in the balance sheet.
  When the companies' actual or forecast emissions are higher than the quotas allocated by the State and still held under the relevant period of the National Allocation Plan (NAP), a provision is recorded to cover the excess allowances.
- The aforementioned provision is equivalent to the acquisition cost up to the amount acquired on the spot or forward markets, and based on market prices for the balance.
- The provision is cancelled when quotas are surrendered to the State. Forward purchases and sales of quotas carried out as part of trading activities are recorded in compliance with IAS 39 and stated at fair value on the balance sheet date. Changes in fair value are taken to the income statement.

Third approach:

- Carbon allowances granted are considered as a current intangible asset and recognised at their fair value at the date of grant and as deferred income and does not subsequently re-value the intangible asset.
- Carbon allowances liabilities incurred are recorded as a current liability.
- Purchased emission allowances are reported as intangible assets under current assets at cost less accumulated impairment losses, while carbon allowances that have been received free of charge from the respective countries' authorities are stated at a value of SEK nil. As CO_2 is emitted, an obligation arises to deliver carbon allowances to the authorities in the respective countries.
- When carbon allowances liabilities exceed the carbon allowances held, the net liability is measured at the market price of allowances.

- Forward carbon contracts are measured at fair value with gains or losses arising on remeasurement being recognised in the income statement. The intangible asset is surrendered at the end of the compliance period reflecting the consumption of the economic benefit and is de-recognised at its original value. As a result, no amortisation is booked but an impairment charge may be recognised should the arriving value exceed market value.
- An expense and a liability are booked only in cases where the emission allowances that were received free of charge do not cover this obligation. This liability is valued in the amount at which it is expected to be settled.

Fourth approach:

- Carbon allowances which are allocated to the company without charge in application of NAP's are recognised on the asset side of the Consolidated Balance Sheet at their fair value with a credit to "deferred income".
- This deferred income is taken to "other operating income" on the Consolidated Income Statement as the CO_2 emissions for which the allowances were granted are actually emitted.
- Allowances acquired from third parties are measured at acquisition cost. These assets are measured at cost and are analysed at each balance sheet date for impairment.
- Carbon allowances are derecognised when they are sold to third parties, have been delivered or expire. When the allowances are delivered, they are derecognised with a charge to the provisions made when the CO_2 emissions were produced. The company records a provision for contingencies and expenses in order to recognise the obligation to deliver carbon allowances in accordance with the methods provided for in the NAP's.
- The amount of the provision is determined on the assumption that the obligation will be settled: through the emission allowances transferred for no consideration to the companies under the NAP or through other emission allowances in the Consolidated Balance Sheet that were acquired subsequently.

  For the portion of emissions covered by the allowances granted under these plans or by allowances acquired by the group, the provision is accounted in the value at which these allowances were initially recognised on the balance sheet. If it is estimated that it will be necessary to deliver more carbon allowances than recorded on the balance sheet, the provision for this shortfall is calculated based on the market price of the allowances at the balance sheet date.

4.3 Energy Industry

Under the European Directive 2003/87/EC establishing the EU-ETS, several energy companies were granted carbon allowances free of charge. Under the Directive, each year the sites concerned have to surrender a number of allowances equal to the total emissions from the installations during the previous calendar year. Therefore, the company may have to purchase carbon allowances on pollution rights markets in order to cover any shortfall in the allowances required for surrender. As there are no specific rules under IFRS dealing with the accounting treatment of carbon allowances, the companies in the energy industry decided to apply the following carbon accounting principles:

- Carbon allowances are classified as inventories, as they are applied in the production process.
- Carbon emissions granted free of charge are recorded in the balance sheet at zero value.
- Emission rights purchased in the market are recognized at acquisition cost.
- The company records a liability at year-end in the event that it does not have enough carbon allowances to cover its GHG emissions during the period.
- That liability is measured at the market value of the allowances required to meet its obligations at year-end.

However, we have identified other companies in the energy industry that account for carbon allowances as intangible assets and reported under other assets. Under this alternative approach, allowances which are purchased and allowances allocated free of charge are both stated at cost and are not amortized. A provision is recognized to cover the obligation to deliver carbon allowances to the competent authorities. That provision is measured at the book value of the CO_2 allowances capitalized for this purpose. If a portion of the obligation is not covered with the available allowances, the provision for this portion is measured using the market price of the allowances on the reporting date.

4.4 Metal Industry

After analysing the carbon accounting models applied by the companies belonging to the metal industry we can state that different approaches are mainly implemented. Based on these, we can draw the following carbon accounting principles for this industry.

First approach:

- It refers to a company under the European Directive 2003/87/EC. In this case, carbon allowances allocated to the company on a no-charge basis pursuant to the annual NAP are recorded on the balance sheet at zero value.

- Carbon allowances purchased are accounted at their cost.
- Gains and losses from the sale of excess allowance are recognized in the income statement.
- If on the balance sheet date the company is short of allowances it will record a provision through the income statement.

Second approach:

- In an alternative approach, accounting for government granted and purchased carbon allowances is made at nominal value (cost) as an intangible asset. Carbon emissions are not amortized as they are either settled on an annual basis before year-end (matched specifically against actual CO_2 emissions) or rolled over to cover the next year's emissions; impairment testing is done on an annual basis.
- Actual CO_2 emissions over the level granted by the government are recognized as a liability at the point in time when emissions exceed the level granted.
- Any sale of government granted carbon allowances is recognized at the time of sale at the transaction price.

Third approach:

Finally, we appreciated a third model implemented by one company in which carbon allowances are recognised as intangible assets and stated at the cost of acquisition.

- Moreover, carbon allowances acquired free of charge under the NAP by virtue of Law 1 of 9 March 2007 are initially measured at replacement cost, which is generally the market value of the allowances at the time of their receipt.
- A capital grant is recognised for the same amount and included under deferred income.
- Carbon allowances are not amortised but expensed when used.
- Valuation adjustments are made as appropriate to reflect any reduction in market value at the end of each year providing that the carrying amount is not considered to be recoverable against future income or expected to be realised through the cancellation of the provision for GHG emissions.
- Provisions are released when the factors leading to the valuation adjustment have ceased to exist.
- A provision for liabilities and charges is created for expenses related to GHG emissions. This provision is maintained until the company is required to settle the liability by surrendering the corresponding allowances. These expenses are accrued as GHG is emitted.
- When an expense is recorded for rights acquired free of charge, the corresponding deferred income is taken to operating income.

Table 2 Carbon allowances account variations

	Carbon allowances number	Valuation (in thousands of €)
Balance at 31/12/07	295,772	2296
Allocation for the year	278,698	6251
Disposals	−295,772	−2296
Balance at 31/12/08	278,698	6251
Allocation for the year	278,698	4431
Disposals	−207,268	−4649
Balance at 31/12/09	350,128	6033

Source Own elaboration

For this company, and according to the 2008–2012 NAP, 1,393,490 free of charge carbon allowances were allocated, representing 278,698 allowances for each year of the five-year plan. This company consumed 142,329 carbon allowances in 2009, and therefore it was not necessary to acquire any additional allowances in the market. The company has not sold the surplus rights. The Company consumed 207,268 carbon allowances in 2008, and therefore it was also not necessary to acquire any additional allowances in the market. Finally, the company obtained lower emissions in 2010 than the allowances allocated for the year. Table 2 shows the movements in carbon allowances account during the last years for that company.

After a comprehensive review of the existing carbon accounting models from an international scope, Table 3 summarizes the main trends of carbon accounting principles applied by the different industries analyzed.

5 Conclusions

A series of conclusions can be drawn considering certain limitations due to the short time that has passed since countries began implementing the contents of the KP. It appears that the most firms belonging to sectors that are internationally recognized as polluters report accounting policies on GHG emissions in their financial annual reports. However, a small percentage indicates that they do not recognize the allowances since there is no guidance from regulators. In relation to this consideration, firms in developed countries offer better information regarding carbon accounting than firms operating in emerging markets. Another consequence of the variety of acceptable carbon accounting models is that the differential effect on financial statements depends on which model is adopted. This has significant implications not only for companies' financial performance reported in the profit or loss account, but also on how a company may decide to manage their participation in the ETS. In the majority of the firms analysed, carbon allowances are recognized as an intangible asset within current assets and are initially recorded at cost and subsequently at the lower of cost and net realisable value. For allocations of emission

Table 3 Trends in carbon accounting principles among industries

	Petroleum	Utilities	Energy	Metal
Initial recognition—*Allocated* allowances	Carbon allowances are recognised as an intangible asset an are measured at acquisition cost	Carbon allowances are recognised as an intangible asset within current assets and are initially recorded at cost and subsequently at the lower of cost and net realisable value	Carbon allowances granted free of charge are recognised in the balance sheet at a value of zero	Carbon allowances are recorded on the balance sheet at zero value
Initial recognition—*Purchased* allowances		Carbon allowances purchased are recorded as intangible assets at acquisition cost	Carbon allowances purchased in the market are recognized at acquisition cost	Allowances purchased are recorded at cost
Recognition of liability	The potential difference between available quotas and quotas to be delivered at the end of the compliance period are accounted for as liabilities and measured at fair market value		The company records a liability at year-end in the event that it does not have enough allowances to cover its GHG emissions during the period	Actual CO_2 emissions over the level granted by the government are recognized as a liability at the point in time when emissions exceed the level granted
Measurement of liability			Liability is measured at the market value of the allowances required to meet its obligations at year-end	

allowances granted by the relevant authorities, cost is deemed to be equal to the fair value at the date of allocation. Receipts of such grants are treated as deferred income and are recognised in the income statement over the period to which they relate. Companies will therefore need to disclose their carbon accounting policy to the market to ensure that its impact on financial performance is understood. Market participants may expect a comparable carbon accounting model across industries. However, as emphasized by this work, a company's carbon accounting policy choice may affect its profits quite differently, particularly where it is not only an emitter but also a carbon trader. Thus, it is essential for the companies that such differences and the reasons for them are intelligible for investors and other stakeholders.

Although GHG emissions, ETS's and other related mechanisms and issues have been developing in different countries, there are still many issues pending. One of them is how to manage carbon allowances in accounting. Although there was a first initiative known as IFRIC 3, it was subsequently not approved because of the modifications proposed by different institutions. However, the IFRIC is reconsidering the different interpretations to improve the accounting quality of the financial information resulting from IFRIC 3 (IASB 2008).

Another important aspect is the information concerning GHG emissions that firms all around the world should include in their annual reports, environmental reports and websites. Thus, Freedman and Jaggi (2005), in a study to evaluate disclosures on pollution and GHG by firms domiciled in countries that have ratified the KP compared to others, consider current costs to reduce the GHG emissions and information on the extent of GHG emissions, among others.

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The Attributional-Consequential Distinction and Its Applicability to Corporate Carbon Accounting

Matthew Brander and Francisco Ascui

Abstract Methods of carbon accounting have developed in a number of semi-isolated fields of practice, such as national inventory accounting, corporate carbon accounting, project level accounting, and product life cycle assessment, and there appears to be considerable potential for learning across these different fields. One methodological distinction that has emerged within the field of life cycle assessment (LCA), and which has been highly useful there, is that between attributional and consequential methods. However, this distinction has not been fully developed or explored within the field of corporate carbon accounting. Attributional methods provide static inventories of emissions allocated or attributed to a defined scope of responsibility, while consequential methods attempt to measure the total system-wide change in emissions that occurs as the result of a decision or action, such as the decision to produce one extra unit of a given product. Numerous LCA studies show that attributional inventories can ignore important indirect or market-mediated effects that occur outside the scope of the analysis, and thus decisions based on attributional information can result in unintended consequences. Given that the most widely recognised form of corporate carbon accounting (the organisation-level greenhouse gas inventory) is attributional in nature, it is probable that decisions based on such inventories may also result in unintended consequences. This paper explores the nature of the attributional-consequential distinction and its applicability to corporate carbon accounting. In addition, the concept of framing is used to help explain how the distinction developed within the field of LCA, and to highlight the conceptual work required to achieve a degree of consensus around the distinction within that community, which in turn may be helpful when considering its applicability beyond the field of life cycle assessment.

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1 Introduction

Methods of carbon accounting (used here as shorthand for all forms of greenhouse gas related accounting) have developed in a number of semi-isolated fields of practice, such as national inventory accounting, corporate carbon accounting, project level accounting, and product life cycle assessment, and there appears to be considerable potential for learning across these different fields (Ascui and Lovell 2011). One methodological distinction that has emerged within the field of life cycle assessment (LCA), and which has been highly useful there, is the distinction between attributional and consequential methods (Finnveden et al. 2009). However, this distinction has not yet been widely appreciated or explored within the field of corporate carbon accounting. Attributional methods provide static inventories of emissions allocated or attributed to a defined scope of responsibility, while consequential methods attempt to measure the total system-wide change in emissions that occurs as the result of a decision or action, such as the decision to produce one extra unit of a given product (Ekvall and Weidema 2004; Curran et al. 2005). Numerous LCA studies show that attributional inventories can ignore important indirect or market-mediated effects that occur outside the scope of the analysis, and thus decisions based on attributional information can result in unintended consequences (Searchinger et al. 2008; Hertel et al. 2010). While organisations collect many different types of both monetary and physical carbon-related information (Burritt et al. 2011), the most widely recognised form of corporate carbon account is the organisation-level inventory of physical greenhouse gas emissions, typically produced for the purposes of voluntary carbon disclosure (but which may also be produced for mandatory reporting, participation in emissions trading schemes or internal management purposes), following standards such as the GHG Protocol (WBCSD/WRI 2004), Defra reporting guidance (Defra 2009, 2013) or ISO14064-1 (ISO 2006c). These standards guide the production of corporate carbon accounts that are attributional in nature (CDP 2013; Brander and Wylie 2011) and thus it is probable that decisions based on such inventories may, like attributional LCAs, result in unintended consequences. Applying the attributional-consequential distinction to corporate carbon accounting may therefore be useful for choosing appropriate methods to inform decision-making, and for understanding the nature and limitations of mainstream (attributional) corporate carbon accounting more generally.

This chapter is structured in two parts. The first part provides an introduction to the attributional-consequential distinction, including a chronology of the development of the distinction, an analysis of the core features of attributional and consequential approaches, examples of the results obtained from each method, and an overview of the critical discussion in the literature concerning the distinction. The second part of the chapter then considers the applicability of the distinction to corporate level accounting, and discusses the utility of the distinction for designing coherent corporate carbon accounting methods, the implications for corporate-level accounting, and the potential usefulness of the distinction for academic research on social and environmental accounting.

The existence of the attributional-consequential distinction in one field (LCA) and its absence in a cognate field (corporate carbon accounting) begs the broader question of *why* this should be the case. While we cannot offer a definitive answer to this question, we believe that the history of the emergence of the distinction in LCA demonstrates that thinking in terms of the systemic consequences of a decision or action, rather than in terms of attributing responsibility for a given situation, involves a conceptual shift—a subtle change of emphasis with far-reaching implications—that is challenging and difficult to introduce when the dominant thinking is attributional. The change of emphasis has different disciplinary roots and is clearly self-evident in one tradition and not in another. This suggests that attributional and consequential methods are not equally available methodological alternatives, but rather that they are bound up with a broader set of preconceptions about how the world works, what matters and how we should respond to a given situation, or what scholars across a range of disciplines would call 'framing'. Framing refers to "the processes by which people construct interpretations of problematic situations, making them coherent from various perspectives and providing users with evaluative frameworks within which to judge how to act. …Framing is problematic because it leads to different views of the world and creates multiple social realities." (Rein and Schon 1993, p. 147). This does not mean that differences in framing, such as the difference between attributional and consequential accounting methods, are irreconcilable; rather, recognition of frames facilitates the more effective use of different approaches in their appropriate contexts. The concept of framing is an additional explanatory thread that we return to in a number of places in the chapter. In particular, we believe this level of analysis helps to explain the observed pattern of resistance and recognition in the development of the distinction in the field of LCA, which in turn suggests that recognising its implications for corporate-level carbon accounting may be similarly challenging, yet ultimately highly beneficial for both academic research and practice in this area.

2 The Attributional-Consequential Distinction

2.1 Chronology of the Distinction

In order to understand the development of the attributional-consequential distinction it is useful to first look briefly at the development of LCA more generally, as it is in LCA that the distinction first developed and is still primarily employed.

LCA can be defined as the "compilation and evaluation of the inputs and outputs and the potential environmental impacts of a product system throughout its life cycle" (ISO 2006b). One of the motivations for the development of LCA was the recognition that for a complete account of a product's environmental impact it is necessary to look at all its life cycle stages (i.e. material extraction, manufacturing, transportation, use phase, and end-of-life disposal), rather than only individual stages, such as the use phase (Guinee et al. 2011). LCA typically includes a number of environmental impact categories, such as human toxicity, resource deletion, eutrophication, greenhouse gas emissions etc., and therefore has a broader scope than carbon accounting. However, the development of the attributional-consequential distinction relates equally to the carbon impact category, as to any other impact category, and the multi-impact nature of LCA does not seem to pose any fundamental limitation on the lessons that can be transposed from this field of practice to 'pure' carbon accounting.

LCA emerged in the 1960s and 1970s, and initially focused on resource use, energy, and waste (Guinee et al. 2011). Following a number of initial studies, which were primarily undertaken by companies (Hunt and Franklin 1996; Jensen et al. 1997), the practice of LCA was formalised in a number of guidance documents, for example, the *Hand-book of Industrial Energy Analysis* (Boustead and Hancock 1979); and later, the *Manual for the Environmental Life Cycle Analysis of Products* (Guinee et al. 1991); the *Environmental Life Cycle Assessment of Products: Guide and Backgrounds* (Heijungs et al. 1992), and the *Life Cycle Assessment: Inventory Guidelines and Principles* (Vigon et al. 1993).

In 1993 Weidema noted that none of the recently published guidance or manuals "adequately reflects the importance that market aspects and the economic disciplines may have in life cycle inventory methodology" (Weidema 1993, p. 161). Weidema suggested that "the use of environmental data on the marginal production reflects most correctly the actual environmental impact" (Weidema 1993, p. 163), and that inventories should reflect "to the largest extent possible, the actual consequences of implementing the results of the investigation" (Weidema 1993, p. 166). This emphasis on quantifying the consequences of a decision or action, as distinct from quantifying the total environmental burdens associated with the processes directly used by or connected with the entity studied, is the essence of the 'consequential' approach.

The fact that the attributional-consequential distinction did not appear until some 30 years into the development of LCA demonstrates that it was not initially self-evident to those involved. A full examination of the communities involved in LCA is beyond the scope of this chapter, but Weidema's mention of "market aspects and the economic disciplines" strongly suggests a new recognition of a different framing of the world (by economists) within a field previously dominated by engineers and natural scientists: as Earles and Halog (2011, p. 445) put it: "CLCA [consequential LCA] represents the convergence of LCA and economic modelling methods". In fact, Weidema (2003, p. 166) explicitly calls for "an interdisciplinary approach… where technical experts, market experts and economists join forces".

After this call to action, it still took time for this elucidation of an alternative framing to be adopted by other members of the LCA community. During the 1990s a small number of studies began to identify and model the processes that change as a result of a decision (the so called "marginal processes"—terminology explicitly borrowed from economics). For example, Ekvall et al. (1998) used marginal data to study the environmental impact of different forms of packaging for beer and soft drinks, and Frischknecht states that to "reflect the consequences of decisions, models capable of representing changes within the economic system shall consist of processes represented by marginal technologies, the technologies put in or out of operation next" (Frischknecht 1998, p. 67).

The formalisation of both the consequential and attributional methods has developed since the late 1990s through the publication of further standards, guidance, and a number of key journal articles on methodological issues. On the consequential side, the key publications include: Weidema (1999) which proposes a 5-step process for identifying the marginal technologies that change as a result of a decision; Weidema (2003) which is a detailed report for the Danish Environmental Protection Agency on the use of market information in life cycle assessment; Ekvall and Weidema (2004) which brings together guidance from various sources on how to determine which technological processes to study and how to identify marginal data; and Schmidt (2008) on system delimitation for agricultural products.

Nevertheless, despite the work represented by this proliferation of guidance, the distinction has not always been clear to different members of the LCA community. Even at the level of basic terminology, convergence on the terms "attributional" and "consequential" required a process of deliberate consensus-building. These terms were adopted in 2001 at an international multi-stakeholder workshop on electricity data (Ekvall and Weidema 2004; Curran et al. 2005), but prior to that, and in fact until as recently as 2009 (see Nielsen and Høier 2009), authors had used a variety of terms to refer to essentially the same distinction. Attributional methods have been variously denoted by the terms "retrospective", "accounting", "descriptive", "book-keeping" and "traditional", while consequential methods have been denoted by the terms "prospective", "market-based", "decision-based", "change-oriented" or "marginal" (European Commission et al. 2010).

In addition to confusion created by the use of different terms, awareness of the attributional-consequential distinction has also not been helped by the existence of influential standards which do not mention the distinction (ISO 2006a, b), fail to clarify whether the standards are intended to cover attributional or consequential approaches, or both (Geyer 2008; Ekvall and Finnveden 2001; Ekvall 1999; Tillman 2000; Brander and Wylie 2011). The International Reference Life Cycle Database System (ILCD) handbook (European Commission et al. 2010) is another internationally recognised source of guidance on LCA, which has contributed to the confusion in a slightly different way. The handbook clearly acknowledges and discusses the attributional-consequential distinction, but it also identifies four distinct application contexts, and structures the guidance on methods accordingly. Unfortunately, it is not always transparent which of the distinct application contexts correspond to attributional or consequential methods, or whether a mixture of methods is at play in the different application contexts.

At this point in time in the LCA community there appears to be growing consensus; Finnveden et al. (2008, p. 365) state that there "is today a general agreement within the life cycle assessment (LCA) community that there are two types of LCA… These are often called attributional and consequential LCA". However, even with this "general agreement" and the increasing usage of the distinction in the

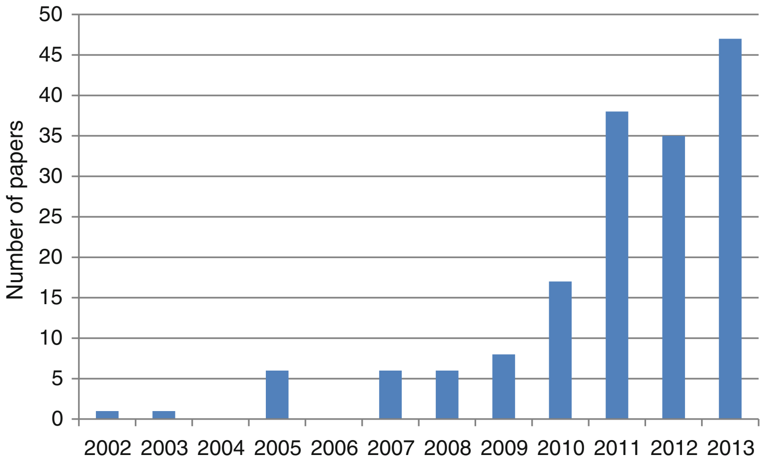

Fig. 1 Number of papers referring to the attributional-consequential distinction by year of publication.

academic literature (as shown in Fig. 1),[1] there is still a continuing and lively debate on a number of issues, such as the correct purpose of each method, and the relative advantages of each (as will be discussed later in the chapter).

In summary, this brief history of the development of the attributional-consequential distinction within the field of LCA shows that the distinction was not initially self-evident to those involved (only emerging some 30 years into the development of the field) and that acceptance of the distinction since the early 1990s has been gradual, uneven and contested, all the way from the level of basic terminology up to fully developed international standards and guidance manuals. The alternatives have different disciplinary origins, with the consequential approach bringing concepts borrowed from economics to a field previously dominated by engineers and natural scientists. Deliberate consensus-building efforts have led to convergence on the terms 'attributional' and 'consequential', but there is still a lack of coherence on the distinction in various international standards and guidance manuals. These features all suggest that attributional and consequential methods

[1](Word searches for the terms "attributional" and "consequential" were conducted on the web sites for the journals listed below. Articles that used the terms in ways other than to refer to the attributional-consequential distinction were excluded. The journals included in the search were: International Journal of Life Cycle Assessment; Journal of Industrial Ecology; Journal of Cleaner Production; Energy Policy; Environmental Science and Technology; Waste Management Resources, Conservation and Recycling; Environmental Research Letters; Ecological Economics; Environmental Science & Policy; Climatic Change; Agriculture, Ecosystems and Environment; Waste Management Research; Nature Climate Change; Greenhouse Gas Measurement and Management; Social and Environmental Accountability Journal; Science; European Accounting Review; Critical Perspectives on Accounting; Climate Policy; Accounting, Organisations and Society; Accounting, Auditing and Accountability; Accounting Forum.)

are not simply two equally available methodological alternatives, but rather two different ways of framing an accounting problem. Nevertheless, a process of reframing, that is still underway, has led to wider appreciation of the distinction and hence to a better understanding of the applicability of each of the alternatives in different contexts.

2.2 Key Characteristics of Attributional and Consequential Approaches

Many authors (Ekvall 2002; Ekvall and Weidema 2004; Curran et al. 2005; Ekvall et al. 2005; Schmidt 2008; Earles and Halog 2011) have proposed definitions or descriptions of attributional and consequential forms of life cycle assessment.

Two key characteristics can be drawn from these various descriptions:

1. Firstly, consequential assessments are concerned with describing change, whereas attributional assessments are a description of a static state. The results from a consequential assessment represent the amount by which emissions change between one state or scenario and another, while the results from an attributional assessment are for absolute quantities of environmental impacts, for a single given state or scenario (Ekvall 2002; Curran et al. 2005; Ekvall et al. 2005).
2. Secondly, consequential assessments are concerned with total changes wherever they occur, whereas attributional assessments are only concerned with the environmental impacts physically used by or produced by the life cycle under analysis (Ekvall and Weidema 2004; Earles and Halog 2011).

A number of other subsidiary features that distinguish consequential from attributional methods can also be identified in the definitions in the literature, but these can be understood as methodological techniques for fulfilling the two key characteristics identified, rather than being essential characteristics in their own right. These subsidiary features include:

1. *Use of economic modelling*. Economic modelling methods are often a characteristic of consequential LCA and are used to identify the processes affected by changes in demand and supply. For example, in Ekvall and Andræ (2006), reduced demand for lead due to the promotion of lead-free solder reduces the price of lead and increases its use elsewhere—and this additional usage is then included in the analysis. Most consequential assessments model market-mediated effects, but with varying degrees of sophistication, ranging from simple identification of market trends and the most/least competitive technologies (e.g. Weidema et al. 1999) to the use of sophisticated computable general equilibrium models (Searchinger et al. 2008; Hertel et al. 2010).

   Attributional LCA, in contrast to consequential LCA, only considers the physical flow of resources to, and impacts from, the physical processes used during the life cycle of the product, and does not model market-mediated effects.

2. *System expansion*. System expansion (or "substitution") is a method for dealing with co-products (or other forms of multi-functionality) whereby credit is given to the product studied for the environmental impacts that are avoided due to its co-products replacing alternative forms of production (Heijungs and Guinée 2007). For example, beef co-products from the dairy industry replace dedicated beef and pork production, and the avoided impacts due to the avoided production are credited to the production of milk (Thomassen et al. 2008).
   In contrast, attributional LCA tends to allocate emissions between co-products, on the basis of physical characteristics such as mass or energy content, or alternatively economic value (Thomassen et al. 2008; Schmidt 2008). There is continuing debate within the LCA community as to whether attributional LCA can also use system expansion, with some standards allowing its use (WBCSD/WRI 2011b; European Commission et al. 2010). However, Brander and Wylie (2011) suggest that doing so introduces values for avoided emissions into what should only be an inventory of actual physical emissions or removals.
3. *Source of data*. Attributional LCA uses either data for the specific physical processes used in the life cycle of the product, or average data, such as average emissions from grid electricity (Curran et al. 2005). Consequential LCA only considers marginal data, which provide information on the processes that change, rather than the processes that are physically used in the life cycle of the product studied (Schmidt 2008). For example, if there is an additional unit of demand for electricity then the generation technology that is deployed to meet that demand is the marginal process. Similarly, if there is one less unit of demand then the generation technology that is reduced is the marginal process (Curran et al. 2005).

A summary of the key and subsidiary characteristics of the attributional-consequential distinction is presented in Table 1 (modified from a similar table in Thomassen et al. 2008).

2.3 Significance of the Difference Between the Methods

An important question is whether using an attributional method rather than a consequential method produces materially different results, to the extent that different decisions would be taken had the alternative method been used. If the methods tend to produce similar results then there is little practical significance to the attributional-consequential distinction. However, if the methods produce very different results, then there is at least a possibility that different decisions would be made if information from the other method was available.

A number of papers have applied both attributional and consequential LCA methods to the same product in order to understand the difference in results generated. Ekvall and Andræ (2006) found very little difference between the attributional and consequential results for lead-free solder, and the assessment by

Table 1 Key characteristics of the attributional-consequential distinction

		Attributional	Consequential
Key characteristics	What is described or modelled?	Static inventory of absolute emissions and removals	Change in emissions or removals caused by a specific decision/action
	System boundary	Physical processes used in life cycle under analysis	Any process that changes as a result of the decision studied
Subsidiary characteristics	Economic modelling	Not used	Often used
	Treatment of co-products/multi-functionality	Disagreement on whether system expansion (substitution) should be used	System expansion (substitution) used
	Data	Process-specific or average	Marginal

Dalgaard et al. (2008) of soybean meal found that the results from using the consequential method (721 gCO_2e/kg of soy meal) were only trivially different to the attributional results (726 gCO_2e/kg of soy meal). However a number of key impacts were not included in the latter study, such as the avoided emissions from deforestation due to the soy oil co-product replacing palm oil, which could have lowered the consequential results considerably (see Schmidt 2010 for the significance of land use change on the emissions from palm oil).

Thomassen et al. (2008) found that the consequential results for milk production (901 gCO_2e/kg of milk) were significantly lower than the attributional results (1560 gCO_2e/kg of milk) due to beef co-products from the dairy industry replacing dedicated beef and pork production, and thereby avoiding large quantities of emissions. Similarly, Viera and Horvath (2008) found that the attributional results for concrete were higher than the consequential results, but that the decision supported by the information would be the same, i.e. recycling concrete is shown to reduce emissions in both cases.

However, there are cases where the decision supported by an attributional account is markedly different from that supported by a consequential assessment. A seminal paper for consequential LCA is a study by Searchinger et al. (2008) on indirect land use change caused by increased demand for biofuel crops. US government biofuel policy was predicated on the fact that attributional LCAs show corn ethanol to have lower emissions than conventional gasoline (74 gCO_2e/MJ of corn ethanol compared to 92 gCO_2e/MJ of gasoline). However, using cropland for biofuels displaces food production elsewhere in the world, and some of the new cropland is likely to be converted from ecosystems such as forests or grasslands, resulting in high losses of stored carbon. Searchinger et al. showed that if the emissions from indirect land use change are taken into account the emissions for corn ethanol are in the region of 177 gCO_2e/MJ of fuel, or 93 % higher than gasoline. Other studies, such as Hertel et al. (2010) have since replicated this work and produced lower emission estimates, but still found that US biofuel policy is likely to increase greenhouse gas emissions.

The magnitude of difference between attributional and consequential LCA results clearly depends on the specific product that is studied. However, it is also clear that in some cases the difference can be very large, and using a single method for a given purpose (such as using attributional methods to inform policy-making) can result in unintended or negative outcomes, as with US biofuel policy. The appropriate uses for each method is one of the main contentions in the literature, and this is discussed next.

2.4 Contentions in the Literature

A long-running debate in the LCA literature is over whether there is any purpose for which an attributional approach is more appropriate than a consequential one (and if the distinction can be transposed to corporate-level accounting, the question is whether there is any purpose for mainstream attributional corporate carbon accounting that could not be better served by an alternative consequential method). Wenzel (1998) suggests that the only purpose of an LCA is to inform decision-making, which implies that the only appropriate method is a consequential approach, as it is this approach that explicitly aims to quantify the total consequences of decisions. There does appear to be a strong case for favouring consequential over attributional LCAs in most application contexts, such as those listed in ISO 14044 (ISO 2006b):

(a) identifying opportunities to improve environmental performance;
(b) informing decision-makers for priority setting and process design;
(c) selecting indicators of environmental performance; and
(d) marketing

Each of these application contexts either implicitly or explicitly involves decision-making, and therefore warrants a consequential approach. For example "marketing" suggests that consumers may use the information to make decisions about which product to buy, and if consumers want to choose a product that causes the lowest environmental impact, then they will need a consequential assessment. Similar considerations apply to the other application contexts as well.

Tillman (2000) agrees that all LCA is either directly or indirectly concerned with change, but argues that there is still a role for attributional accounts, for instance, in identifying emissions 'hot spots' that can be targeted with abatement actions. However, this appears to beg the question, "How do we know that our actions to manage hot spots don't have unintended consequences?" which suggests that a consequential assessment is still needed to operationalize the attributional information.

An alternative attempt to carve out a role for attributional LCA is made by Ekvall et al. (2005). They give the example of a Swedish energy user that could be incentivised to isolate its hydropower plant from the electricity grid in order to avoid having to account for electricity consumption using the emission factor for the marginal technology in the Nordic electricity grid, which is coal. Doing so would increase emissions at the system level, as excess hydropower from the plant would no longer be supplied to the grid. Attributional accounting would not incentivise this behaviour, as the energy user could report the low emissions from its hydropower. However, it is not clear that consequential accounting would truly incentivise an increase in emissions. If a consequential approach were applied to the question, "What will happen if the energy user isolates its hydropower from the grid?" the answer would be "It will increase emissions", and decision-making based on minimising total system emissions would lead the energy user to maintain the connection of its hydropower plant to the grid.

Arguments about ease of application are often intermingled with arguments about the purpose of attributional and consequential approaches. For instance, many of the arguments in favour of attributional accounting in Tillman (2000) centre on the difficulties in identifying marginal processes or in undertaking system expansion (rather than arguing that attributional methods are conceptually more appropriate). Advocates of consequential LCA, particularly Weidema (2003), have argued that the consequential approach is actually simpler, as only those processes that change need to be modelled, and once the marginal product for a sector has been identified, this can be used for all other assessments that involve that sector. For instance, all consequential assessments involving changes in demand for vegetable oil only need to consider palm oil, as this is the marginal form of vegetable oil (Schmidt and Weidema 2008).

However, the claim that consequential accounting is simpler is not borne out by the take-up of the approach. Despite the apparent superiority of a consequential approach in most application contexts, attributional LCA continues to have greater levels of usage. For instance, the Carbon Trust's Carbon Footprint Label (Carbon Trust 2013) is based on the PAS 2050 (British Standards Institute 2011) and GHG Protocol (WBCSD/WRI 2011b) methodologies, both of which are attributional in nature. The main reason for the continued preference for attributional accounting appears to be the complexity of consequential modelling, and the difficulty in sourcing marginal data (which was the experience reported by Ekvall and Andræ (2006) in their case study for lead-free solder). Another suggested reason is the greater comprehensibility of attributional results, as users may struggle with conceptualising market-mediated or system wide impacts (Thomassen et al. 2008).

There is one application context for LCA where an attributional approach could genuinely be more appropriate (and not just easier to apply), and that is in measuring absolute environmental burdens, such as the total emissions associated with consumption (Zamagni et al. 2012). The results from attributional LCAs are additive and do not double-count the impacts included in other product life cycles, thus the sum of attributional results should approximate total actual impacts (Tillman 2000). In contrast, the results from consequential assessments are non-additive, and reflect changes in emissions rather than absolute emissions. Attributional accounts could therefore be used for setting consumption ‘budgets’ in order to meet normative targets for absolute total emissions (such as 450 ppm atmospheric CO_2 concentrations), whereas consequential accounts cannot be used in this way. However, as with the ‘hot spot’ application context discussed above, consequential methods would still be needed to inform decisions on changes in consumption practices, product design etc., to avoid unintended consequences outside of individual attributional budgets.

These ongoing debates illustrate that even after a process of what Rein and Schon (1993, p. 159) call “frame-reflective discourse” leading to a degree of shared understanding within a given community, disagreements can remain, either between different sub-groups within the community, or between the community and others, as illustrated by the problem of making consequential results as easily comprehensible as attributional results, to users of this information. Again, this does not imply irreducible conflict, but rather highlights the fact that frame-reflective discourse needs to be iterative and responsive to changing situations. After all, eternal consensus may be just as undesirable as eternal conflict or misunderstanding.

3 Application of the Attributional-Consequential Distinction to Corporate Carbon Accounting

We now turn to the question of whether the attributional-consequential distinction, which has developed within the LCA literature, may also be useful within the field of corporate-level carbon accounting. A first point to make is that the characteristics of attributional accounting identified in Table 1 (i.e. providing an inventory of actual emissions and removals; and the inventory boundary defined in terms of the processes physically or directly connected with the reporting entity) match the characteristics of corporate level carbon accounting, as prescribed by accounting standards such as the GHG Protocol Corporate Standard (WBCSD/WRI 2004) or ISO 14064-1 (ISO 2006c). In other words, these standards provide guidance for the production of accounts which can be described as being attributional in nature (Brander and Wylie 2011; CDP 2013).

To the best of our knowledge, no direct equivalent to consequential (vs. attributional) LCA exists as a methodology or standard for corporate-level carbon accounting, in the sense of guiding the production of a consequential version of the typical organisational greenhouse gas inventory. Indeed, it may be impossible to hope to capture all of the possible consequences of a company’s actions or to define baselines against which change can be measured in a meaningful way, particularly for companies operating in competitive markets, within cap-and-trade schemes, or dealing in relatively uniform commodities. Decisions to create, re-design or cease manufacturing a single product are routinely made and offer relatively clearly defined alternatives for comparison, whereas change at a corporate level is rarely so simple. Nevertheless, clearly companies do also routinely make decisions or choices between different alternatives—at a range of levels from strategic to tactical and operational—which may have different greenhouse gas implications, even if these alternatives may be more complex and difficult to define than alternatives at a product level. Therefore, in principle, there is no reason why a consequential assessment could not be undertaken to evaluate the systemic consequences of any particular action or choice made by an organisation, rather than relying solely on attributional information to make the same evaluation. Differences in the unit of analysis might help to explain the earlier and wider acceptance of the distinction in LCA, but this does not seem sufficient to explain its near total absence in corporate carbon accounting.

This section identifies a number of areas where greater awareness of the distinction may be beneficial to corporate level accounting: promoting coherence in corporate carbon accounting standards; clarifying the most appropriate choice of accounting method to answer specific types of question; and informing carbon accounting research more generally.

3.1 Issues with Coherence in Corporate Carbon Accounting Standards

Although the literature on the attributional-consequential distinction focuses almost exclusively on LCA, there are some instances in standards or guidance documents where the distinction is recognised in relation to corporate carbon accounting. One example is in the CDP's guidance note on corporate reporting of emissions from electricity consumption:

> The attributional approach is the approach adopted by the GHG Protocol *Corporate Standard* for corporate inventories. A consequential approach, on the other hand, tries to answer the question "What are the systemic consequences (changes) in total (system) emissions from given policy decisions at product/entity level?" (CDP 2013, pp. 12–13).

Here the distinction is applied to corporate carbon accounting rather than product LCA, and the context of its use is to ensure that consequential methods are not confused with, or introduced into, attributional accounts. A similar provision is made in the GHG Protocol Corporate Standard itself, though without explicit reference to the attributional-consequential distinction:

> These reductions [i.e. reductions in emission sources not included in the inventory boundary] may be separately quantified, for example using the GHG Protocol Project Quantification Standard, and reported in a company's public GHG report under optional information… (WBCSD/WRI 2004).

Despite these instances where the attributional-consequential distinction has been used to ensure the methodological coherence of greenhouse gas accounting practice, there are also cases where greater awareness of the distinction would have been useful. Although the European Commission's Organisation Environmental Footprint method (European Commission 2013) is a multi-impact method rather than being solely focused on carbon accounting, it nevertheless provides an example of a standard that mixes attributional and consequential elements as it includes credits for avoided emissions (or other environmental burdens) within what would otherwise be an attributional inventory (see Pelletier et al. 2013). Organisational inventories based on this method will be neither an account of absolute emissions and removals (or other environmental burdens), nor an account of the total consequences from the reporting company's activities. A more thorough understanding of the attributional-consequential distinction could help to avoid such methodological mix-ups. While perhaps the European Commission's method represents an attempt to merge or reconcile the attributional and consequential approaches, we suggest a conceptually more coherent approach would explicitly recognise, rather than try to remove, their differences.

A further example of confusion is provided by the GHG Protocol's recently proposed guidance on reporting emissions associated with electricity generation, known as 'scope 2' emissions (WBCSD/WRI 2014a). As shown in Table 1, the processes included in attributional accounts are based on a physical relationship with the reporting entity in question. However, the GHG Protocol guidance allows the use of contractual emission factors that do not reflect any physical relationship between the reporting company and the contracted emissions rate. In addition, the suggested justification for using contractual emission factors for scope 2 reporting is to promote a *change* in the total amount of renewable generation (although the guidance also allows the use of contractual emission factors even if there is no evidence of change in the amount of renewable electricity generated). If *change* in renewable generation is the desired outcome then this could be better supported and accounted for separately using a *change*-oriented method (i.e. a consequential method), such as project level accounting, rather than mixing this into what would otherwise be purely attributional accounts.

3.2 Clarifying the Most Appropriate Choice of Accounting Method

In addition to promoting conceptually coherent carbon accounting standards, the attributional-consequential distinction could be useful in choosing the appropriate method for a given application. As was shown in the field of life cycle assessment, consequential methods appear to be the most appropriate for decision-making contexts (such as comparing two alternatives with respect to a desired outcome) as they explicitly aim to quantify the total consequences of decisions. In the Searchinger et al. (2008) example, decisions based on attributional methods can result in system-level outcomes that are the exact opposite to those intended. Given that corporate level carbon accounting is attributional in nature (CDP 2013; Brander and Wylie 2011), it is probable that such accounts will be similarly unreliable for good decision making. This fundamental shortcoming, which is due to the fact that attributional accounts do not capture the full system-level impacts of a given alternative, should be understood as distinct from other limitations on comparability which have to do with a lack of consistency in accounting and reporting, as observed by many authors (Kolk et al. 2008; Solomon et al. 2011; Andrew and Cortese 2011; Dragomir 2012; Sullivan and Gouldson 2012). A greater appreciation of the attributional-consequential distinction could encourage the use of consequential methods, such as project level accounting or consequential LCA, to inform or appraise corporate decision making.

One possible application context for attributional corporate level accounting is to provide information on exposure to regulatory risk. Given that many regulatory measures such as carbon taxes and emissions trading schemes impose responsibilities on emitters based on attributional accounting methods, one reason for companies reporting such information might be to indicate the risk of such liabilities in future. Attributional accounts will then be decision-useful for investors interested in the financial impacts of such impositions on the valuation of corporate assets (Hassel et al. 2005; Kolk et al. 2008). However, questions would remain about the efficacy of regulation based on attributional methods, precisely for the reason that they do not show the total consequences of a corporation's activities, nor the impact of regulating those activities. Out-sourcing of emissions-intensive activity to a country not covered by such regulation might be an example of a perverse outcome that would only be recognised with a consequential assessment. Companies and investors relying on attributional accounting should therefore also consider the risk that policy-makers could change the emphasis of regulation to capture more non-attributional impacts in future, if these consequences are material at a systemic level.

A common explanation for the different application contexts for attributional and consequential methods is the scope of the decision under analysis. It may be assumed that consequential methods are only necessary if whole markets or industries are affected by the decision in question, and where this is not the case then attributional methods are sufficient. However, it is possible to conceive of micro-level decision scenarios that do not affect whole markets, but nevertheless require a consequential approach to capture systemic impacts. For example, if a farmer purchases straw from a neighbour to use as a fuel, the neighbour may have to use more fertiliser as they are no longer ploughing the straw back into the soil. A conventional corporate level inventory for the farmer would not capture the indirect effect of the neighbour's increased fertiliser use, and, moreover, it would only be through undertaking a consequential assessment and comparing it with an attributional assessment that the systemic adequacy of using an attributional approach could be known.

It could also be suggested that expanding the scope of attributional corporate inventories will help to capture more of the consequences of corporate activities, thereby mitigating the problem of missing system-level impacts. Indeed, this appears to be part of the rationale for the provision of guidance on including all scope 3 sources (i.e. sources of emissions not controlled by the reporting company, but occurring either upstream or downstream in their value chain) in corporate accounts (WBCSD/WRI 2011a). However, emission consequences, especially where they are mediated by markets, can occur well beyond the value-chain of the reporting entity in question, and so will not necessarily be captured even by whole value-chain inventories. For example, consuming an additional unit of a product in one country may affect production of the marginal unit in another country; value-chain analysis will only capture the upstream and downstream impacts from the former unit and not the latter. In contrast, a consequential approach will attempt to provide 'complete' information, as it specifically aims to identify all the emission sources that are affected by a decision or action.

In some sectors, there is already some awareness of this limitation to attributional corporate accounting. For instance, the telecommunications industry makes the case that although its own value chain emissions may be increasing, the industry's services reduce emissions in other sectors, such as transportation (e.g. by video conferencing replacing business travel). A recent report commissioned by the telecommunications industry calculates the abatement potential from telecommunications to be approximately seven times larger than emissions from the sector (Global e-Sustainability Initiative 2012). Similar consequential impacts, which would not be captured in a conventional attributional inventory, are reported by BASF who claim a 246 million tonne reduction in CO_2e emissions due to their sustainable building products (BASF 2014). Awareness of the limitations with value-chain attributional accounting is also evidenced by the GHG Protocol's proposal to develop a standard specifically focused on product-enabled reductions (WBCSD/WRI 2014b). It is interesting (but not surprising, given the self-regulatory nature of most such initiatives in corporate carbon accounting) to note that the current focus of these initiatives is on the beneficial *reductions* caused by company activities, with little interest yet shown in understanding the possible *increases* in emissions that may occur outside conventional attributional inventory boundaries.

It is possible that companies may be using consequential methods to support *internal* decision-making, but not public reporting, and therefore their use is not evident. However, a more likely possibility is that companies are using attributional methods to inform their internal decision-making, as it is on the basis of these accounts that companies will be judged by their external stakeholders, because the attributional approach currently dominates public reporting. In addition, attributional corporate accounting standards, such as the widely used GHG Protocol Corporate Standard, state that the information provided by such inventories should be relevant to *decision making* (WBCSD/WRI 2004, pp 7–8), which clearly suggests that attributional accounts will be used in this way. The question of whether companies are using attributional or consequential methods to support their internal decision-making is a subject for further empirical research, but it is worth noting that such research is only likely to take place if the attributional-consequential distinction becomes more widely recognised within the carbon accounting research community, which in turn requires the sort of frame-reflective dialogue and consensus-building that previously occurred within the LCA community.

Despite the limitations with attributional corporate accounting, one feature of attributional accounting which appears to be lacking with consequential methods is the sense of 'ownership' conferred on emissions within a company's attributional inventory. Conventional attributional accounts provide a starting point for companies to recognise a set of emissions as 'theirs', which they can then seek to manage over time. In contrast, with consequential accounting, it is more difficult to identify which emission sources the company 'owns'. What may be needed is a combination of both approaches, with attributional accounts used to establish a set of emission sources to be managed, and consequential assessments used to inform decisions on how to reduce those emissions without causing unintended consequences elsewhere in the system.

A next step for companies interested in understanding and managing the total system-level greenhouse gas impacts of their decisions would be to utilise or develop consequential methods that capture both reductions and increases in emissions resulting from specific actions or choices. A number of methods already exist that can be used for this purpose. Consequential LCA can be used where the decision concerns the production or design of a specific product. Although there are no published standards dedicated to consequential LCA, helpful guidance is available in Ekvall and Weidema (2004) and in Weidema (2003). Project level accounting can be used where the decision concerns a discrete activity, e.g. the development of on-site renewables (see WRI and WBCSD 2005 or ISO 14064-2 2006d for guidance). Finally, policy-level accounting can be used for assessing company policies, e.g. economy-class only business travel, or making payments for employee-owned car mileage (see the GHG Protocol's Policy and Action Standard (WBCSD/WRI 2013) for guidance).

3.3 Utility of the Distinction to Academic Understanding of Carbon Accounting

A final area where a greater awareness of the attributional-consequential distinction may be fruitful is to academic research on corporate carbon accounting. As mentioned earlier, despite its widespread use within the field of life cycle assessment, there appears to be very limited use or awareness of the attributional-consequential distinction in the academic literature for other areas of carbon accounting. The only journal article identified (based on the literature review illustrated in Fig. 1) that uses the attributional-consequential distinction to categorise different fields of greenhouse gas accounting practice is Brander and Wylie (2011), which suggests that national inventories and corporate greenhouse gas accounting are attributional in nature, and that project and policy-level accounting are consequential. The lack of other literature suggests that utilising the distinction to understand the different forms of greenhouse gas accounting is relatively underdeveloped at present. Likewise, the attributional-consequential distinction only appears in one of the eight journals covered by Ascui's (2014) review of the 'social and environmental accounting' (SEA) literature on carbon accounting (the exception being the *Journal of Cleaner Production*, which has a strong focus on LCA). Ascui (2014) distinguishes between critical/normative discussions *about* carbon accounting, and empirical studies *of* carbon accounting. It appears likely that the attributional-consequential distinction could be pertinent to both these areas of research.

It is worth noting that the attributional-consequential distinction is not equivalent to the distinction between financial accounting (external reporting) and management accounting (internal decision-making) (Ratnatunga 2008; Burritt et al. 2011; Stechemesser and Guenther 2012). Internal decision-making may or may not be based on attributional accounts, and external reporting may provide either attributional or consequential information. As previously observed, an important area for further research is the extent to which current corporate level decision-making is based on attributional information, and whether this leads to sub-optimal outcomes at the system level.

4 Conclusions

There appears to be considerable potential for wider learning from the conceptual and methodological development of the attributional-consequential distinction in the LCA literature. With respect to corporate carbon accounting, the potential benefits include the development of more coherent carbon accounting standards, and a better understanding of the appropriateness of relying on attributional versus consequential accounts to answer different kinds of query. In short, attributional accounts provide a snapshot of a particular scope of assumed responsibility, which may be relevant to corporations concerned only with regulatory liabilities based on attributional accounting. However, given the global, systemic nature of climate change as a problem, consequential accounts are appropriate for informing decision-making where the objective is genuine mitigation of the problem (i.e. based on a much wider sense of responsibility). Attributional accounts may also be useful for managing absolute carbon budgets, and for creating a sense of 'ownership' for a specific set of emissions. However, if actions aimed at reducing emissions within an attributional budget or inventory are not informed by a consequential assessment, it will be impossible to know whether the actions also cause unintended consequences elsewhere in the system. Further research is required to develop heuristics or simplified methods to understand when such consequences may be material or not. The use of consequential assessment for corporate level decision-making could also be greatly facilitated by a standardised methodology, potentially bringing together aspects of consequential LCA, project-level accounting, and policy-level accounting. The challenges of developing such a methodology, however, should not be underestimated.

Despite superficial similarities (e.g. presenting results in the same metric, such as carbon dioxide equivalents), attributional and consequential accounts are not alternative methods for answering the same question, but rather, methods suitable for answering fundamentally different questions, informed by different disciplinary perspectives and conceptual frames. "[H]ow you account for CO_2 emissions and the answer you get depend on the questions you ask, the framework of the query" (Marland et al. 2013). Problems arise, however, when this distinction is not appreciated. It is hoped that this chapter provides an initial contribution to further frame-reflective debate on the nature and utility of the attributional-consequential distinction for corporate carbon accounting, which may facilitate more rapid adoption of common terminology, standards and associated conceptual understanding than was the case with its earlier emergence in the field of LCA.

Finally, this chapter has focussed on the potential application of the distinction to corporate carbon accounting, but there is considerable scope for further research to explore the application of the concept and methods to other forms of carbon accounting. It may be helpful, for example, to understand that national inventories are also generally attributional in nature, while project and policy-level carbon accounting are consequential (Brander and Wylie 2011). Policies aimed at managing national emissions may well create effects that are not captured in attributional national inventories, and alternatives such as consumption-based accounting (Barrett et al. 2013), while including more consequences, will not necessarily be sufficient to fully capture system-wide marginal impacts. Beyond this, the distinction may prove fruitful to other forms of social and environmental accounting: we suspect that similar issues would be raised in accounting for water, biodiversity, health or employment impacts, for example. In each case, appreciating the distinction may support a better understanding of possible alternatives and the appropriateness of using different alternatives to answer different questions.

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Implementing an EMA Innovation: The Case of Carbon Accounting

Delphine Gibassier

Abstract Environmental management accounting (EMA) has only been researched as an innovation on rare occasions. This research focuses on EMA as an innovation for several reasons. First, environmental deterioration is clearly visible, widespread and deep-rooted, and many scientists are warning that urgent action is required to remedy the situation. Second, the way that the accounting profession tackles the environmental issue will indicate its capacity to evolve with the rest of society. Third, it is of importance and relevance to organizations, because according to an Accenture/Global Compact 2010 survey, 96 % of CEOs agree that sustainability issues should be integrated in company strategy and operations. This research focuses solely on the implementation phase of the innovation cycle. Indeed, implementation is an uncertain exercise and may prove complex and problematic. Accounting innovations often fail to be successfully implemented or disseminated throughout the organization. Therefore, this research seeks to answer the question of how a radically new EMA innovation can be implemented in a company. Consequently, this research develops a case study of the implementation of carbon accounting in a French multinational, and explores the different factors that led to the successful implementation of the innovation.

1 Introduction

Environmental management accounting (EMA) has only been researched as an innovation on rare occasions. For example, Rikhardsson et al. (2005) explored the question of whether EMA could be a fad or fashion, wondering under what conditions EMA could endure. Lafontaine (2003) also tried to characterize environmental accounting as a managerial innovation or an accounting innovation,

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deciding that EMA could not be defined as an accounting innovation because of the accounting profession's lack of involvement in this definition. EMA is herein referred to as one type of management accounting innovation (MAI). MAIs refer to "newer" or modern forms of management accounting and control systems (Zawawi and Hoque 2010). Environmental uncertainties, recent global issues such as climate change or the scarcity of natural resources can affect MAIs (Zawawi and Hoque 2010). Interaction between these issues and MAIs therefore needs further investigation (Zawawi and Hoque 2010). This research focuses on the EMA innovation for several reasons. First, environmental deterioration is clearly visible, widespread and deep-rooted, and many scientists are warning that urgent action is required to remedy the situation (Costanza et al. 2013). Second, as Medley (1997) stated, the way that the accounting profession tackles the environmental issue will indicate its capacity to evolve with the rest of society. Third, it is of importance and relevance to organizations, because according to an Accenture/Global Compact 2010 survey, 96 % of CEOs agree that sustainability issues should be integrated in company strategy and operations.

This research focuses solely on the implementation phase of the innovation cycle. Indeed, implementation is an uncertain exercise and may prove complex and problematic (Rogers 2003). Accounting innovations often fail to be successfully implemented or disseminated throughout the organization (Abernethy and Bouwens 2005). Therefore, this study seeks to answer the question of how a radically new EMA innovation may be implemented in a company and consequently develops a case study of the implementation of carbon accounting in a French multinational, exploring the different factors that led to the innovation's successful implementation.

The paper is organized as follows: Sect. (2) presents the literature on implementing EMA. Section (3) introduces the subject of this research. Section (4) introduces the qualitative research method and describes the case study company. Section (5) presents our findings and describes the implementation of carbon accounting within the organization studied. Finally, Sect. (6) discusses case study findings and draws subsequent conclusions.

2 Literature Review: Implementing Environmental Management Accounting Innovations

Implementing innovation within an organization can be defined as the process of obtaining targeted employees' appropriate and committed use of this innovation (Klein and Sorra 1996). The implementation period is when the tensions between the organization and innovation are revealed, tensions created by the uncertainties that innovations bring with them and the rationalization of the current organizational model (Alter 1993). Often, new management accounting techniques are adopted while older systems are maintained, suggesting that there is a transitional stage in the implementation of management accounting innovations (Zawawi and Hoque 2010). Moreover, MAIs can have consequences not only through the new visibility and calculability it provides the organization, but can also drive the organization to reorganize itself. Hoque and Alam (1999) observed that the management accounting system implemented in their case study motivated a change in the organization, which became more decentralized and project-oriented in keeping with Total Quality Management (TQM) ideals. Implementation also relates to issues of organization knowledge. Fiol (1996) invites us to think of organizations as sponges, some of which have a greater capacity to absorb new knowledge than others. “Depending on their absorptive capacity and on their ability to reconfigure what they have absorbed, organizations also have more or less potential to generate outcomes” (Fiol 1996). In their development of “absorptive capacity”, Cohen and Levinthal (1990) emphasize prior experience with related knowledge as a key determinant. Others have focused on the importance of an internal “champion” to carry the innovation forward (Daft 1978; Brown et al. 2004; Emsley et al. 2006).

The very complex, uncertain and problematic exercise of implementing innovations breeds tensions between role-players, and causes realignments as new practices, roles and systems appear, redefining existing ones. Many studies in accounting literature have investigated accounting changes and failures, emphasizing how the fate of an innovation is determined by the action of others (Preston et al. 1992) and concluding that the bundling of innovations needs to be reconceptualised to incorporate managerial and organizational learning processes (Modell 2009). The literature on implementing innovations has emphasized the potential barriers to successful implementation (Kasurinen 2002). Some are structural barriers, such as organizational culture. Another cause of resistance is the inability to secure legitimacy for the accounting innovation when it does not speak the same language as daily ongoing operations (Scapens and Roberts 1993). Finally, a failure in the change management process—such as the absence of a sponsorship process and/or educational efforts—is also considered a potential barrier to successful implementation (Kasurinen 2002).

What this research seeks to add to our understanding of implementation processes is how a radically new EMA innovation was successfully implemented in a multinational. This study responds to a call by Kasurinen (2002) to investigate the factors and implementation approaches that make successful change possible. We shall therefore describe the emergence of the new practices, roles and systems, and how the employees appropriated the innovation. Indeed, appropriation of an innovation lies in the realm of “doing”, i.e. in the creation of new practices (Gaglio 2011). Pantzar and Shove (2010a) believe that innovations in practices occur through the connections between foundational elements such as material, image and skills. In this research, we describe the development of material practices, new skills and roles around the EMA innovation.

3 The Subject of Research: Carbon Accounting as an EMA Innovation

Over the last ten years, greenhouse gas (GHG) emissions have emerged as the key environmental indicator for organizations. Climate change has developed into the most prominent and well-known environmental issue today (Giddens 2008). The definition of carbon accounting in this research is:

> The recognition, the non-monetary and monetary evaluation and the monitoring of greenhouse gas emissions on all levels of the value chain and the recognition, evaluation and monitoring of the effects of these emissions on the carbon cycle of ecosystems. (Stechemesser and Guenther 2012)

Carbon accounting can be defined as a radical innovation, as it requires new and different practices to complement a change in strategy (Emsley et al. 2006). Carbon accounting is not a mere improvement of existing practices.

In this research, we are only concerned with the physical evaluation of GHG emissions. Carbon accounting occurs at different scales. The first is national carbon accounting, which was developed after the signing of the Kyoto Protocol so that countries could account for their emissions. Carbon accounting has also been developed for cities and regions (e.g. France's "*bilan carbone des territoires*" (carbon budget for sub-national entities), Global Protocol for Community-Scale GHG Emissions).

The second carbon accounting scale is that of corporations. Three types of carbon accounting concern corporations: by site, product or project. Project carbon accounting is concerned with carbon-offset projects. This method of accounting is specific to projects conducted in general after reductions have been made within a corporation and therefore outside the scope of this research. We are thus concerned by product and site carbon accounting. Both types are linked and results converge theoretically, although very few organizations have tried to associate the two in reality. Site accounting is based on the GHG Protocol Corporate Standard from 2001, revised in 2004. It focuses on how each site emits greenhouse gases. Its results are therefore production-based. The GHG Protocol Corporate Standard is closely linked to the responsibility framework from financial accounting and the boundaries are based either on equity or financial control. One last possibility is to base results on operational control, which is the most difficult to implement as it is very different from existing data collection systems based on traditional financial accounting. The second type is product accounting, which is mainly used for companies that focus on certain products either for eco-design purposes or to inform consumers of the CO_2 impact of product consumption. Some companies have tried to transform this accounting method into a large-scale method by accounting for hundreds or even thousands of their products' carbon footprints, but to our knowledge, none has tried to devise a company-wide result using product footprints (i.e. based on turnover rather than production) (Fig. 1).

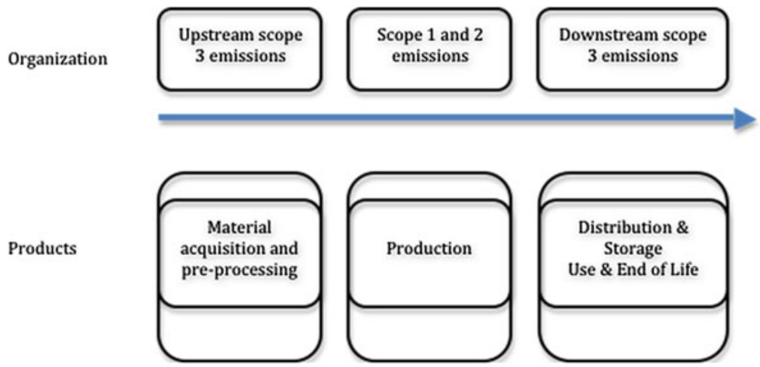


Fig. 1 The link between corporate and product carbon accounting (GHG Protocol 2011)

Carbon accounting within organizations is still under-researched (Burritt et al. 2011; Schaltegger and Csutora 2012). A study of automobile manufacturers in South Korea (Lee 2012) revealed that although many firms adopt a carbon inventory in scopes 1 and 2 under the GHG Protocol and national South Korean standards, indirect emissions from the total supply chain to the production gate (Scope 3) are critical for automobile manufacturers. Therefore, Lee suggests that automobile manufacturers should practice an eco-control approach "which includes setting goals and implementing internal and external communication in a systematic way". Lee argues that for automobile manufacturers, it is vital to define a carbon management strategy which engages key suppliers in a process through which they gradually become part of a sustainable supply chain. However, this study does not reveal how carbon accounting has actually been implemented and sustained within the organizations investigated. Moreover, Burritt et al. (2011) have argued that although their study revealed a wide range of carbon-related accounting activities such as collecting monetary and physical carbon data for investment decision-making or operational costs, companies need to consider a more sophisticated organization and design of carbon management accounting. This is what our research will explore in a single case study.

4 Research Design

The case study is a preferred method when examining contemporary events over which the investigator has little or no control, and to answer "how" and "why" questions (Yin 2009). Moreover, case studies allow an interpretation of the social system being studied (Scapens 1990). A case study is "an exploration of a bounded system over time through detailed, in-depth data collection involving multiple sources of information rich in context" (Creswell 1998). In the social and environmental accounting literature, it has also been argued that there is a need for more approaches focusing on organizations that practise sustainability accounting, with the "aim of drawing from the field the rationales that the actors use to construct sustainability accounting and accountability and, directly or indirectly, enhancing practice" (Adams and Larrinaga-Gonzalez 2007). Therefore, we believe case studies with their major participant observation approach respond to the call for more engaged approaches with organizations.

To study the implementation phase of an EMA innovation, a single case study was conducted in a multinational company. Global multinational enterprises (MNEs) currently represent an immense share of the global economy [if WalMart were a country, for instance, it would be the 22nd largest in the world in terms of GDP, as per Keys and Malnight (2010)] and are accused of being responsible for much of the environmental damage (Gray and Bebbington 1998). In contrast, Hawken (1993) says that business is the only mechanism powerful enough to produce the changes necessary to reverse global environmental and social degradation. MNEs therefore attempt to not only avoid being accused of causing the damage but rather to be a driving force in remedying environmental damage (Gunningham 2009). Consequently, this research concentrates on one MNE to seek to understand its involvement in the environmental debate around sustainability (Gray and Bebbington 1998) and to contribute to the understanding of this paradox.

The case study company is a medium-sized multinational in the food sector that, while a leader in its market segments, does not represent a mastodon of the food industry worldwide. Its corporate social responsibility (CSR) policy is based on a "dual social and economic project" that dates back to 1972. The environmental aspect of sustainable development has been present within the company since the founder's 1972 Marseille speech:

> Corporate responsibility does not end at the factory gate (…). The energy and raw material we consume change the face of our planet. Public opinion is there to remind us of our responsibility (…) the energy resources of Earth are limited. (Company founder 1972)

In 2000, corporate objectives were set to limit water and energy consumption and reduce waste and packaging. The objectives were achieved earlier than planned and a new strategy was defined starting in 2008. The new strategy, based on four core strategic priorities—Health, For All, Nature and People—was closely aligned with the company's 2006 mission, to "bring health through food to as many people as possible". The CEO clarified the four priorities as follow: "'Health,' that is to say, the company's contribution to public health through nutrition, 'For All', that is to say, the creation of products and economic models accessible to population groups with low purchasing power, 'Nature' to drastically reduce the environmental impact of our activities throughout the lifecycle of our products, 'People' by giving all of our employees the opportunity to develop, to anticipate the changes and to give meaning to their work". He added in the 2009 Sustainability Report, that each of these core priorities must act like a "transformer", a way to rethink the company's methods and invent "new business and social responses".

To coordinate the new 'Nature' environmental strategy, a new department was created in 2009. This 'Nature' department replaced the previous 'Environment' department. The new ‘Nature’ team defined the following five priorities for environmental action: “reducing the carbon footprint, protecting water resources, stepping up packaging research to transform waste into a resource, promoting sustainable agriculture, and supporting biodiversity”.

This research focuses on one of the company’s five priorities, namely “reducing the carbon footprint”, and investigates how carbon accounting played a central role in the development of this strategic objective.

The study dataset is based on the following approach. First, I conducted participant observation for 12 months. Throughout this time, I was in charge of carbon accounting standards, implementation of the accounting tools related to carbon, reporting related to carbon, as well as the convergence project of two accounting methodologies. I interacted daily with carbon masters around the world in relation to carbon accounting topics. Moreover, I interacted with the consultant who created the Excel carbon accounting tool. I also participated in the corporate life of the ‘Nature’ team at headquarters, including team meetings, lunches and informal conversations. During the time in the ‘Nature’ team, I also participated in “green days” in November 2010, aimed at considering past strategy on climate change and nature in general, and at developing the future strategy. I also participated in further meetings related to the future of climate change strategy in 2011. Moreover, I witnessed a stakeholder meeting in November 2012 related to this future strategy. To learn more within the baby division, I participated in a one-day meeting on carbon accounting and strategy in February 2012. In all, I attended 149 meetings in these 12 months. Moreover, semi-structured interviews were conducted to gain knowledge of the early stages of the projects in 2007 to 2009, when there was no participant observation. A total of 30 interviews were conducted in addition to four exploratory interviews with the ‘Nature’ team at the end of 2010. Additionally, meetings were recorded to gain insights into the information circulating and discussions linked to accounting and strategy-making. Finally, secondary documents were collected and e-mails kept to add to my knowledge of organizational practices.

Qualitative researchers interpret data based on the whole of their own experiences, training, social position etc., and there is a general acceptance of the subjectivity of these methods (Bluhm et al. 2011). Moreover, participant observation is said to have strong internal validity in the sense that researchers have time to “learn the language” of participants, and because it is conducted in natural settings, it reflects the reality of informant life experiences (Schensul et al. 1999).

5 Findings

The implementation of radically new management accounting innovations (MAI) requires setting up a new infrastructure, including performance incentives, new roles to be created, methodologies to choose and information system infrastructure to support the development. Moreover, an MAI is often implemented in conjunction with a new business strategy. Finally, MAI implementation often requires a support network to succeed. Therefore, this section describes the roles, methodologies and infrastructure development for carbon accounting, how it was closely integrated into business strategy, while emphasizing the support structure cradling the innovation. New links were created around the innovation for it to be successfully implemented.

5.1 Performance Monitoring, Incentive to Invest and Sponsors

The context in which the environmental and carbon strategy was to be initiated in 2006 and 2007 was highly ambiguous for the food industry in terms of markets, legal frameworks and technologies. Legally, the case study company was not bound like some other corporations by the European Union's Emissions Trading Scheme (EU ETS). However, there was already talk of environmental labelling and a potential carbon tax. The company's water division had also come under environment-related pressure because of campaigns against bottled water. However, in the food industry, strategic issues related to the environment were very vague and undefined at the time, and there were no legal or competitive pressures to kick off a major carbon strategy, with reduction targets and company-wide carbon accounting.

In 2008, the company officially announced the −30 % target and its integration into bonuses. The target was to reduce the CO_2 footprint by 30 % (in kg of CO_2 per kg of product) for all activities (industrial sites, packaging, transportation and both product and packaging end-of-life cycle). The carbon footprint reduction objective was integrated into the bonus system applicable to all general managers of country business units and group directors (1400 people in all) from 2008 to 2012. The bonus played a key role, because it is a sign to managers that this topic is taken seriously by company heads. The inclusion of the reduction target into bonuses motivated everyone in their commitment. However, in the country business units (CBU), it was hard to grasp what it meant, and what kind of actions could lead to that objective:

> I think that at the time, the announcement was for me something I couldn't really relate to. It sounded very abstract, a long way from what we were used to doing in running a country business unit. (General Manager, country business unit.)
>
> In my opinion, on the one hand there was a strategy that everyone embraced. And on the other hand, implementation where everyone implemented, but without necessarily being perfectly aware that it contributed to reducing CO_2. (General Manager, country business unit.)

The implementation of the EMA carbon accounting innovation was a key factor in transforming the abstract goal of reducing emissions by 30 % into the daily operations performed by each business unit. In return, the full integration of carbon accounting into the new strategy led to its successful implementation as an EMA innovation. From 2008 to 2012, the case study company reduced its emissions by 35.2 % with respect to its intensity target.

5.2 *Developing a New Role: The Carbon Master*

Carbon accounting was supported through the inception of a new function, named "carbon master," and a new department in company headquarters known as 'Nature finance.' The company created a community of 110 carbon masters, defined as "facilitators and champions in each subsidiary of the Carbon Reduction Plan" in 2008. First named "carbon expert," carbon masters were appointed in each subsidiary to be responsible for measuring CO_2 emissions and preparing a suitable action plan for their reduction. There were no guidelines given on how the "carbon master" should be chosen, and no indication that a new function should be created. Most of the time, the first carbon masters were actually quality managers, research and development managers, supply chain managers or other managers who simply added this topic to their job description.

In 2012, most carbon masters worked full time on environmental issues. Those that did not, had been able to create small teams, mostly comprising younger employees responsible for carbon accounting, while the carbon master remained in charge of strategy-related work, simulations, and projects with other CBU departments.

At headquarters, the carbon control team is composed of two full-time employees: a 'Nature' CFO, and a carbon controller. One is from an accounting background, the other an engineering background. This scheme corresponds to the current world of carbon accounting, which bridges different epistemic communities (Ascui and Lovell 2012). The team is in charge of carbon accounting quality and leads the process of automation through the project with the Enterprise Resource Planning (ERP) global provider. Moreover, the team is tasked with answering for sustainability ratings—including the Carbon Disclosure Project (CDP)—carrying out the annual reporting on carbon, and strategic monitoring of the rapidly evolving carbon accounting field.

5.3 *Carbon Accounting Methodologies*

The company uses two corporate accounting methods, one by product and the other by site. Both are compiled into a company-wide result. The company aims to make the results of both methodologies converge so as to be able to use both in reporting and in-house management systems.

5.3.1 The Company's Carbon Accounting Methodology by Product

The company's carbon accounting methodology is primarily based on the life cycle assessment (LCA) methodology, ISO 14044, and PAS 2050 from 2008. According to the in-house "carbon accounting methodology guide" from 2010, a successful carbon accounting system should have the following characteristics:

- Comprehensive (scopes 1, 2 and 3)
- Periodic: enables updates at regular intervals and comparison across reporting periods
- Auditable: to trace transactions and enable independent reviews for compliance
- Flexible: incorporates data from multiple approaches to life cycle assessment
- Standard-based: accommodates current generally-accepted standards and emerging standards
- Scalable: accommodates growing volume and complexity of business operations
- Efficient: delivers data in the timeframe required for decision-making.

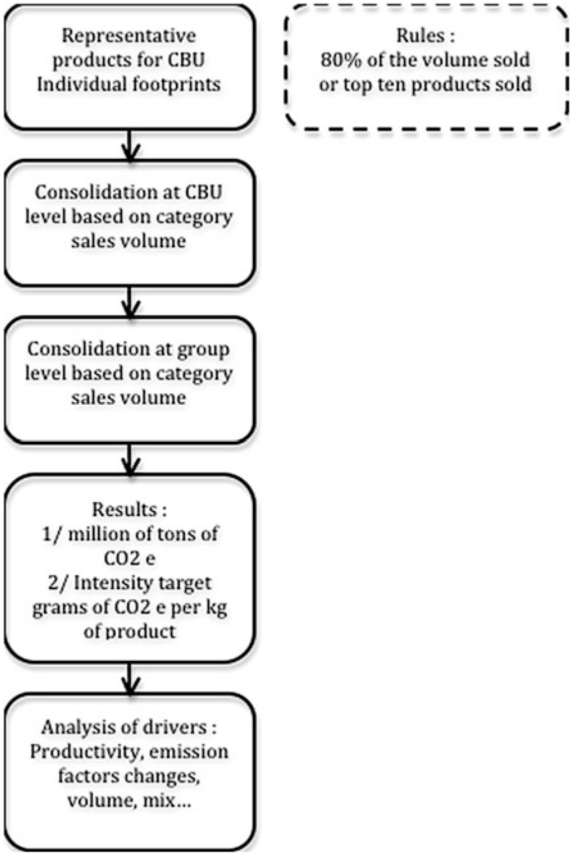
The goals of the approach chosen according to the in-house accounting guide are to:

- Be able to compare the main products of their portfolio based on their carbon footprint
- Help identify action plans to reduce the carbon footprint
- Produce using an eco-design approach
- Communicate on product carbon footprints when possible.

The first step of the carbon accounting methodology consists in measuring the emissions for representative products of a CBU in CO_2 equivalents. The carbon masters fill in data for at least ten product footprints, sometimes more depending on the representativeness of the products in terms of turnover in their country. Individual product footprints are defined in in-house guidelines as: "the total emission of greenhouse gases (GHG) linked to a product across its life cycle, from the production of raw materials to its end of life". The carbon master fills in the following tables: product data (including ingredients and packaging information), logistics data (where the distribution scenario for each country is modelled), manufacturing data, fruit data for dairy products, composite packaging data and warehouse data. Emission factors by country are defined at corporate level and integrated in the tool given to the carbon masters, except when they are calculated based on country assumptions such as chilled storage in shops or at home, and fruit emission factors.

The second step entails aggregating data country-wide, based on the ten most representative product footprints or 80 % of the total turnover footprints (for the water division). The company calculates the business footprint for each country by allocating responsibility on a consumption basis and not on a production basis. For example, a product unit for a yoghurt made in Belgium and sold in France has a footprint partially calculated in Belgium, and the rest of the footprint is complemented with carbon accounting data by the French carbon master for logistics,

Fig. 2 Company carbon accounting



consumption and end of life based on the French market. The total carbon product footprint is then allocated to the French business unit because it ordered the manufactured product (in Belgium) and because the product was sold to the final customer in France. Footprints are calculated for the CBU based on different product category sales.

Finally, the total group footprint is the addition of all CBU footprints. The result is both in millions of tons of CO_2 equivalent and in the efficiency target of grams of CO_2 equivalent per kilogram of product sold (remembering that the accounting is based on turnover and not on production). In all, more than 800 individual product footprints are used to produce the total of the group's yearly results (Fig. 2).

5.3.2 The GHG Protocol Corporate Standard

Since 2012, the company has also been measuring company-wide carbon emissions using the GHG Protocol Corporate Standard (2004) on all its sites (not limited to manufacturing sites). It was tested on four country business units in 2011, and extended to all business units in 2012. It is a comprehensive annual calculation of the company's scope 1 and 2 carbon emissions.

The results are used to reply to the carbon disclosure project questionnaire once a year, and to meet the French requirement to report GHG emissions for scopes 1 and 2 since the end of 2012.

5.3.3 The Convergence Project

Based on the need to bring together different stakeholder views of carbon performance, the company decided in 2010 to initiate the "convergence" project. The aim was to examine whether different accounting approaches could be linked such that the resulting information corresponds to each other. To our knowledge, only one attempt has been made to link corporate and product carbon accounting systems, described in the Journal of Cleaner Production (Scipioni et al. 2012). Their approach allows an organization to determine over time how organization-scale decisions affect a product's carbon footprint. They designed a model that integrates "the life cycle approach of the ISO 14040 standards with ISO 14064 to model the management and monitoring of emissions and to develop an inventory of GHG emissions for products" (Scipioni et al. 2012). However, their study is not two-way (corporate to product and back again), and has only been tested on two products of Tetra Pack Italy.

The two accounting approaches in the convergence project discussed here are, on the one hand, the company's in-house accounting approach and on the other, the GHG Protocol Corporate Standard used to respond to investors' and external rating agencies' needs. The idea is to make sure that the result from the total products' footprints and the result from the total sites' footprint match, to give comprehensive corporate results. The convergence project aims to develop a comprehensive corporate carbon accounting approach which arrives at consistent figures, whether carbon is accounted for with their own in-house management performance accounting system or the externally driven accounting and reporting system complying with international standards (Fig. 3).

5.4 Carbon Accounting Tool: From Excel to SAP

Carbon accounting is a radically new accounting approach for corporations and therefore relies on innovative information systems. The company built a first tool based on Excel technology, and has since 2010 transitioned to an ERP system, jointly innovated with company SAP.

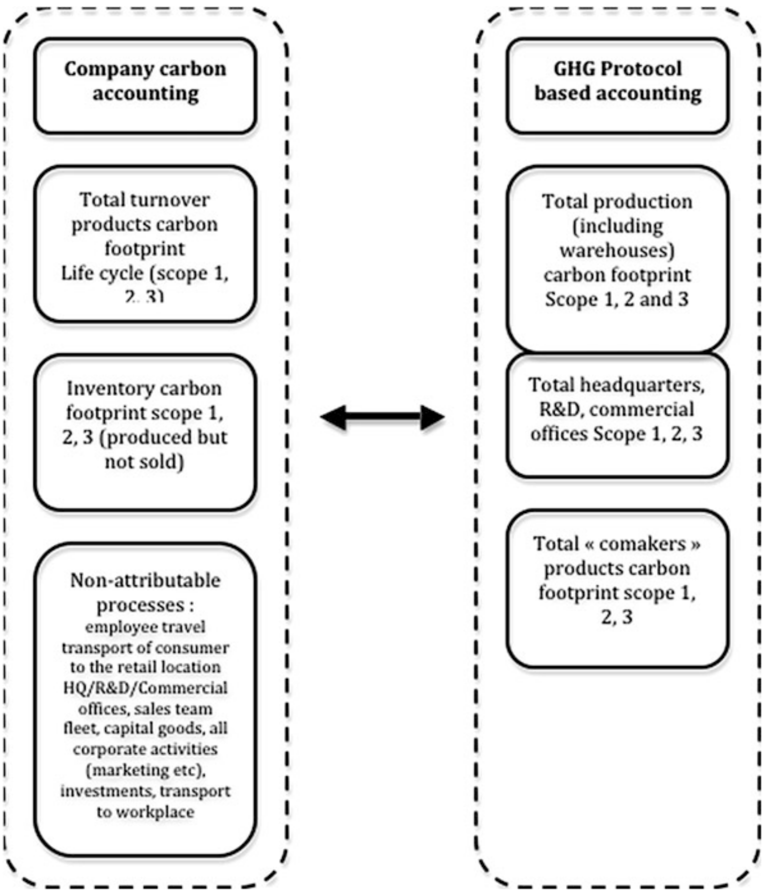


Fig. 3 Convergence of methodologies

5.4.1 Excel-Based Tool

Since 2007, an Excel tool has been used to collect data for individual product footprints. It is applied by the carbon masters responsible for data collection in each CBU to calculate carbon footprints once a year.

The tool provides tables with emission factors and calculation formulas so that the carbon masters need only to fill in activity data for the specific year and some intermediate data for emission factors (ingredients, kilometres, energy consumption, etc.). The Excel tool is composed of four different parts[1]:

[1]Source: in-house methodological guide for the Excel tool.

- An interface where the user enters primary data describing the product and the main characteristics of its life cycle;
- A database on GHG emission factors (ingredients other than dairy ingredients and fruit preparation, packaging materials) as well as average destination of waste in a given country, used to calculate the total carbon footprint of a given product based on the data entered by the user. This global database is country-specific, insofar as country databases exist, otherwise factors are common;
- A calculation engine, based on Excel formulas to calculate the results from the primary data entered by the user, the GHG coefficients and other formulas used to model the life cycle steps included in the system;
- An interface displaying the carbon footprint results of a product. Carbon footprints are presented in two ways: per kg of product (e.g. g CO_2e/kg of yoghurt) and per product unit (e.g. g CO_2e per cup or per bottle).

Following the methodology of two-step consolidation, the first Excel tool calculates individual product footprints, the second extrapolates to the CBU's sales volume, and the third tool consolidates results at company scale.

There are three different versions of the individual footprint Excel tool for the four divisions but each has the same framework with more or less complex functionalities (for packaging, fruit or milk for example). The tool was constructed from 2007 to 2009 by an external consultant, based on an initial design by the company Ecobilan in 2006. The tool was used to obtain certification of products in the United Kingdom by the Carbon Trust in 2008 and subsequently revised and updated. Additionally, it was submitted for analysis to an external auditor, the French environmental agency, and went through two peer reviews in 2009 and 2010. The tool is revised once a year for minor technical updates, and more major emission factors updates (Table 1).

The individual footprint Excel tool is used for three different purposes: budgeting (once or twice a year depending on the division), reporting once a year, and simulating a project's impact on the footprint for planning purposes.

The consolidation tool at corporate level is used for reporting numbers annually in the sustainability report, calculating progress towards the 30 % reduction target of GHG emissions between 2008 and 2012, and to direct and understand the progress through an analysis of reduction drivers. The internal carbon accounting process is defined as follows in Fig. 4.

5.4.2 ERP-Based Too

The ERP-based tool mirrors the Excel tool and is composed of different emission factor books (energy, ingredients, manufacturing and warehouse sites), a calculative tool, and a link to the finance ERP for activity data. Some more complex emission

Table 1 Construction of the Excel tool

Date	Event
2006	Interaction with Big 4 consultant, conceptualization of Excel tool "to be"
June 2007	Construction of first Excel tool by external consultant
July 2007	Presentation of the Excel tool to water division environmental managers
August/September 2007	Testing of the tool in four countries
January 2008	Calculation of footprints for all water divisions for 2007
January–December 2008	Carbon Trust certification on UK products
January–June 2008	Workshops to tailor the Excel tool to the dairy division
July 2008	Presentation of the Excel tool to dairy division environmental managers
September 2008	Announcement of the −30 % target
2009	Medical and Baby divisions: expansion of the tool

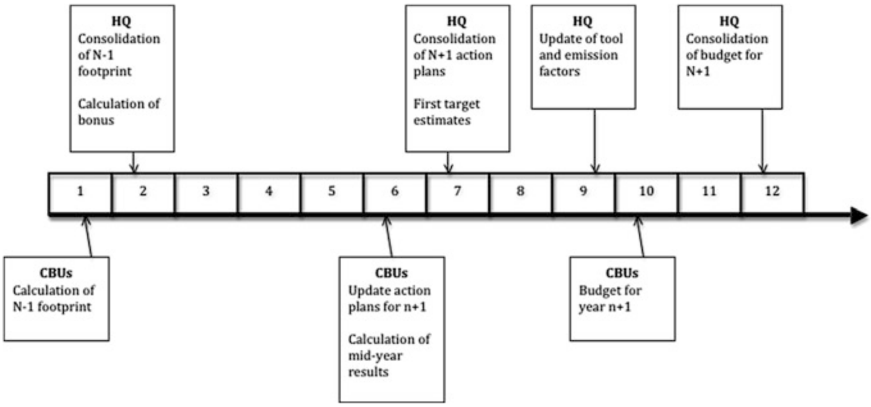


Fig. 4 Yearly process of carbon accounting

factors such as fruit, milk and logistics are still calculated in Excel sheets outside the ERP system and entered manually.

The ERP system allows live data to feed carbon accounting. Carbon accounts are closed monthly so that the carbon master can see their results on a monthly basis rather than Excel's yearly basis. The other major difference is that all the products produced or distributed are taken into account with no extrapolation, which is the basis for the Excel-based calculations. However, contrary to the Excel tool that is used by all CBUs around the world, ERP Carbon is only available where financial ERP is already in operation, and will gradually be implemented in other CBUs as the financial ERP is itself implemented.

ERP Carbon was co-constructed (as a joint innovation project) with the global ERP supplier SAP in 2009. It was tested in two CBUs in 2010 and then rolled out in over 30 countries in 2011 and 2012. A business intelligence tool with reports was deployed in late 2012 to allow for strategic analysis of data.

5.4.3 Other Data Collection Systems and the Convergence of Systems

The GHG Protocol Corporate Standard is currently managed through an external web system, unconnected to the Excel tool or the current ERP Carbon tool. The GHG Protocol calculation tool is however linked to the environmental KPI information system by a backload of energy and refrigerant data from the KPI information system into the GHG Protocol web system.

Additionally, the company has a recently upgraded legacy system to collect key environmental performance indicators, mainly related to regulatory demands. This tool is deployed in all business units and updated once a year. It collects energy, water, waste and other environmental performance indicators.

The company has decided to integrate all these tools and link them together to avoid double entry loads and mistakes. It furthermore wishes to optimize reporting through a consistent data set for regulatory demands, stakeholder reporting and internal management (Fig. 5).

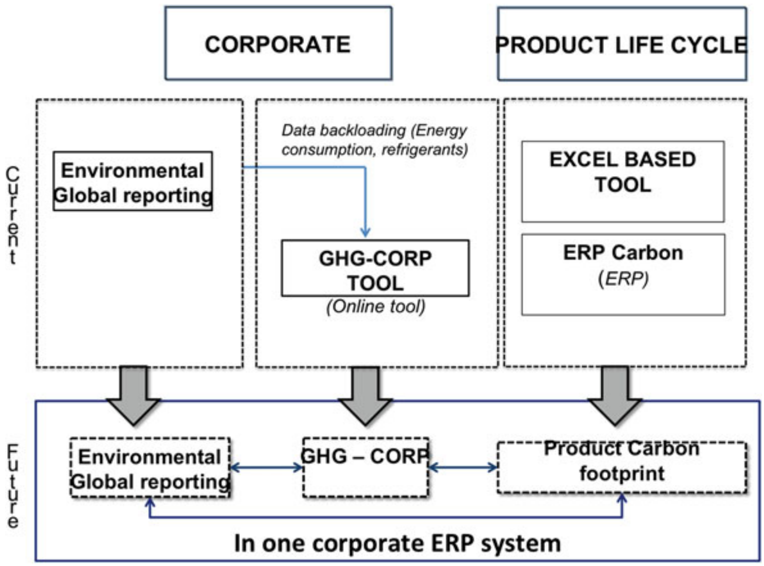


Fig. 5 Convergence of tools

5.5 Closely Integrated with GHG Emission Reduction Strategy

5.5.1 Productivity Strategy

In the first phase, local teams looked for easily quantifiable areas where it would be easy to measure reductions and therefore success. During the first year, business units selected a number of driving forces that would lower carbon in products: one was energy consumption and the second, packaging, which was also very easy to measure. Other factors such as distribution, the in-store context, or the entire supply chain and suppliers were all left for a later step. Therefore, the ease with which carbon accounting could be applied to certain topics determined the first areas to tackle with respect to the reduction of emissions.

5.5.2 Top-Line Strategy

Another strategy developed was to focus on the potential communicability of certain reduction actions, to directly link the strategy of being able to calculate emission reductions to the consumers. In Europe, consumers were informed of several actions to reduce or change packaging. One was linked to the change from traditional plastic to green HDPE for one yoghurt pack, another involved removing packaging all together around yoghurts (the "nude" operation), and the last one was linked to a change in the composition of a water bottle from 100 % traditional plastic to some bio plastic and recycled plastic. For these projects, accounting was sometimes lagging behind strategy, calculations being new or emission factors non-existent. Therefore, in some cases, top-line strategy helped to enhance carbon accounting.

5.5.3 Long-Term Strategy

Another tool was added to foster long-term environmental investment. The criteria for "green" capital expenditure (capex) projects were modified to take into consideration projects that would not fit traditional financial criteria. A new criterion was added so that a project could be considered under the green capex scheme: tonnes of CO_2 saved per million Euros invested. The payback period was calculated using a monetization of CO_2 at about 15 Euros per tonne saved. The criterion for a decision was still made on payback, but included the CO_2 saving monetized.

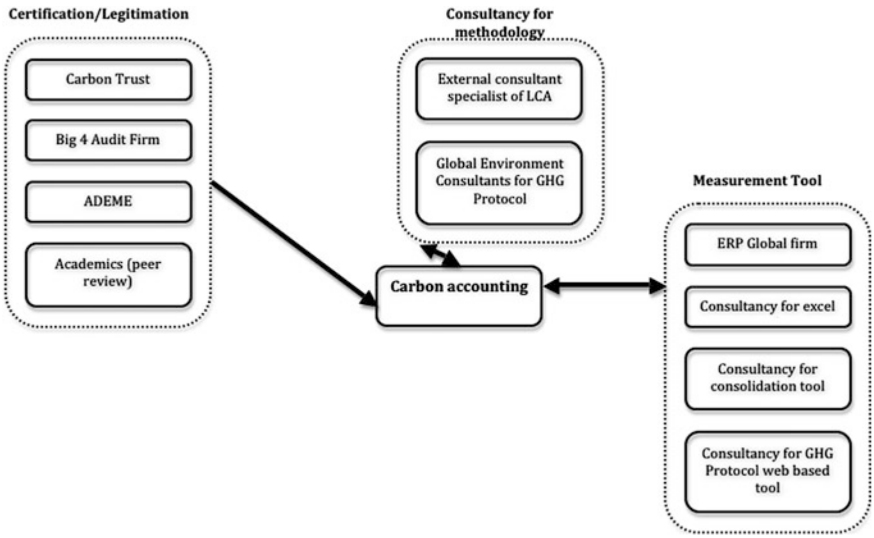


Fig. 6 Support network surrounding carbon accounting

5.6 External Network

Carbon accounting was supported through three types of networks: a methodological network, an infrastructure network and a certification network. The methodological network was composed of a consultant specializing in life cycle assessment and a global environmental consultancy team for the GHG Protocol methodology. The infrastructure network was composed of the global ERP firm SAP, one consultant on the consolidation system in Excel, one consultant to monitor all changes to both the Excel tool and emission factors, as well as a global environmental consultancy team for the web-based tool used to collect the GHG Protocol related data. The certification network was composed of peer review academics, a big four firm and the French environmental agency (ADEME) as well as the Carbon Trust, which performed a critical review when it certified specific products for the UK in 2008 (Fig. 6).

6 Conclusion

Implementation is the critical gateway between the decision to adopt the innovation and the routine use of the innovation within an organization (Klein and Sorra 1996), as innovations are often only considered as such when they are "used" (Gaglio 2011). It is also a sensitive phase, as implementation can be only partial, leading to a phenomenon known in institutional theory as "decoupling", where the tool is mere window dressing for actual practices, and where it never becomes part of daily routine.

While recognising the factors of success mentioned in the literature (Argyris and Kaplan 1994; Brown et al. 2004), including that the new tool be internally legitimate and matched to organizational identity (Gibassier and Journeault 2013), this research brings additional insights to the success factors influencing implementation of an EMA innovation. The company's strong commitment to creating new practices around the EMA innovations, such as a new role (carbon master), new methodologies (carbon accounting based on product footprints), and a new infrastructure (ERP system) was sustained by an innovative incentive system, a high level of integration into the business strategy (cost, top line and long term) and an external support network. As per Shove and Pantzar (2010b), a radical accounting innovation must create the right "links" to become a committed practice within the organization. Therefore, while both structural factors and change management factors are important in the successful implementation of an innovation, the links made through actual practice of a new innovation lead to committed use and results in implementation effectiveness (Klein and Sorra 1996). In this case study, the innovation was closely linked to business strategy, existing financial processes (budgeting, investment, financial ERP system) and external support networks. The innovation is now practised daily as "regular" carbon accounting and continuously enhanced via the development of the role of carbon master, the continuous improvement of the infrastructure and the development of a formal strategy for carbon reduction in the different business areas. This research also helps enhance our knowledge of corporate practice in carbon management accounting (Burritt et al. 2011; Schaltegger and Csutora 2012) with this single case study, which sheds light on the complex structure built up around a radical EMA innovation during its implementation to assure its success (Fig. 7).

Research limitations include the participant observer approach, as external validity can be threatened by the creation of a researcher-informant relationship that would seriously affect the setting or results (Schensul et al. 1999). This occurs when the researcher develops close and trusting relationships with the informants within the company. Relevant tactics are needed to avoid threatening the difficult equilibrium between participation and observation as a researcher. One of the main tactics the researcher used during participant observation was the "outsider" period negotiated with the case study company. The research was conducted in two full-time periods separated by an extensive period outside the company. This period of separation allowed the researcher to consider the data collected and begin thinking about theoretical frameworks. A second tactic used to avoid being affected by the company under study was to discuss it several times per week with other researchers, and to reflect upon the experience with another researcher who had previously used a similar mode of data collection.

Future research on EMA innovations should focus on understanding why sustainability innovations, of which EMA is part, are often institutionalized but poorly disseminated and adopted (Burns and Vaivio 2001). Indeed, there is a need to understand the potential support—or lack of support—from infrastructures,

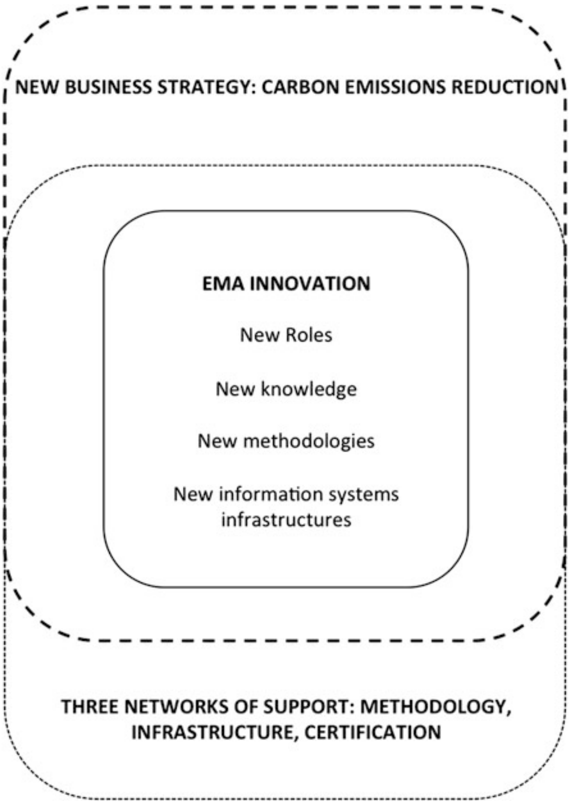


Fig. 7 EMA innovation integrated into business strategy and accompanied by relevant support networks

regulations or user demands (skills to be used) (Brown and Dillard 2013) for EMA innovations. Additionally, Bell and Hoque (2012) challenge researchers to critically assess the inertia created by existing accounting structures, processes and techniques and mainstream those conversations that raise challenges to the status quo. Looking at EMA as an innovation allows us to look at the spaces in which innovations are constructed, the networks they create or could depend upon to develop, and the technologies they must compete with in the current regime (Brown and Dillard 2013). Secondly, future research should analyse how EMA as an innovation contributes to our understanding of how accounting can or might contribute to sustainability transitions. There is a need to understand how the way in which accounting integrates the environment gradually attains the status of self-evidence; or why it does not, and reciprocally, how it is that particular calculative technologies come to be seen as the appropriate way to solve these particular problems (Miller 1991). Finally, studying EMA as an innovation is firmly entrenched in the view that accounting can be changed (and should evolve), and therefore that we cannot mistake "contingent accounting ideas, practices and institutions, local in space and time, as self-evident, universal and necessary" (Gomes et al. 2011).

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Carbon Accounting in Long Supply Chain Industries

Zsófia Vetőné Mózner

Abstract Accounting for indirect carbon emissions embodied in different stages of the supply chain is increasingly important as supply chains become more and more globalised. Embodied emissions are greater when the supply chains of economic sectors are longer, when goods/services that are created in one sector demand significant input from another sectors and when several industries are involved in the supply chain. Simply monitoring and disclosing indirect emissions might not be adequate if the goals of carbon reduction policies are to be met. The paper presents first an overview of relevant literature on carbon accounting within supply chains. It examines the relevance of using hybrid input-output analysis to reveal the indirect impacts in the supply chains of different economic sectors. The paper presents the empirical research with the example of China, a country where goods are often produced to meet the demands of consumers in developed countries. Long supply chain industries and key indirect emission sources which are responsible for a significant proportion of total emissions are identified. A time-series analysis is presented in which the embodied emissions in exported products are analysed from 1995. Results confirm that the use of input-output models is especially relevant for accounting for indirect impacts in long supply chain industries. Corporations in these economic sectors are strongly advised to monitor and keep track of their indirect emissions.

1 Introduction

Concern about the carbon emissions embodied in supply chains is increasing. Carbon emissions generated throughout the entire supply chain need to be accounted for if companies' environmental performance is to be properly evaluated

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(Buritt et al. 2011a, b). Burritt and Tingey-Holyoak (2012) have called for more research to be undertaken into embedded carbon emissions and the opportunities for their management by corporations. The authors state that a gap exists between contemporary research into and knowledge of sustainability-related embedded carbon accounting and the application of these techniques. They also provide a review of carbon accounting research. The accounting methodology for indirect impacts is not yet fully elaborated. Harmonised methodological tools are needed if carbon management accounting (CMA)—which is a part of sustainability accounting—is to further develop. A gap exists in accounting properly for embodied carbon emissions and the responsibility of companies. The use of hybrid input-output tables could help with combining physical and monetary data and accounting for emissions which are not directly connected to a company's activity.

The direct and indirect emissions of economic sectors are significantly different depending on the lengths of their supply chains. The production of goods and services has become decoupled in the sense that supply chains typically extend beyond the borders of countries. Sustainable supply chain management and environmental management accounting are closely interrelated and sustainable supply chain management is of growing importance at companies. Trade barriers have been reduced, allowing goods to be produced at lower cost but with greater efficiency and across national borders (Burritt et al. 2011a, b). Supplying accurate information to managers within economic sectors is essential. Burritt et al. (2011a, b) observed that "only a limited amount of research has been conducted on the practical implementation and use of sustainability management accounting and even less is known about corporate practice on collecting, managing and communicating carbon-related information within companies" (p. 80).

Industrial sectors are interrelated but there are great differences in the volume and value of inputs that some sectors demand from others. Long supply chain industries are defined as being industries where outputs require inputs from many other industries, or where industries provide inputs for many other industries. Long supply chain industries may cause indirect environmental impacts in other economic sectors.

The emission trade balances of countries have recently also become a focus of scientific research (Barrett et al. 2013; Droege 2011; Lenzen et al. 2010). Trade is an important factor in shaping a country's economic structure, but it also contributes to the movement of embodied emissions beyond a country's borders. The question of embodied emissions appear. This is proven by the fact that while the manufacturing sector in Europe has indeed reduced its impact on the climate over the last decade, the emissions increased globally due to the development of international trade and delocalisation of manufacturing industries (European Environmental Agency 2010; Schaltegger and Csutora 2012). Logistics activities may grow by 23 % between 2002 and 2020, representing 18 % of the European GHG emissions in 2020 according to estimations (The Climate Group 2008). Decarbonizing supply chain networks and monitoring embodied emissions is highly important.

The focus of the paper is analysing carbon accounting of economic sectors along their supply chains, especially focusing on indirect, embodied carbon impacts. This paper describes the importance of accounting for embodied, indirect carbon emissions at sectoral level using the example of some long supply chain industries. Section 2 presents an overview of recent empirical findings that confirm the need to account for indirect scope 3 emissions. Section 3 presents briefly carbon accounting beyond country borders. In Sect. 4 the example of Chinese economic sector is analysed and recommendations for sectoral carbon accounting are given.

2 Allocating Carbon Emissions Through the Supply Chain

A company's activity results in the generation of direct and indirect GHG emissions. Emissions can be distinguished according to different 'scopes', depending on how directly the emissions are associated with the company's activities Direct emissions (on-site, internal) are generated during the production and extraction of raw materials and intermediate materials, during the production phase itself.. Direct emissions are the so-called scope 1 emissions. Indirect emissions (off-site, external, embodied, upstream, downstream), which are generated indirectly related to the product, can be further differentiated to scope 2 and scope 3 emissions. Scope 2 emissions include indirect emissions from purchased energy that is used by the company. Accounting for scope 2 emissions may motivate companies to be conscious of their energy demand, reduce the use of carbon intensive energy sources and use increasing share of renewable energy. Upstream and downstream supply chain activities can be accounted for as indirect emissions. Scope 3 emissions include business trips, outsourcing activities, franchise activities, and the commuting of employees as well as indirect emissions from activities such as the extraction and production of materials and fuels that have been purchased, transport-related activities undertaken in vehicles not owned or controlled by the reporting entity, electricity-related activities (e.g. transformation and distribution losses) not covered in scope 2 and outsourced activities and waste disposal (Huang et al. 2009b; Downie and Stubbs 2013). With many companies some scope 3 emissions are included in carbon disclosure reports but only those that arise from the transportation of employees and business trips, while other potential sources of scope 3 carbon emissions are left unaccounted for. To reliably evaluate company performance in the future this should be changed so that all potential scope 3 emission sources are included in reporting. Emission reduction goals and strategies should incorporate all relevant scope 3 emission sources. Figure 1 shows the different scopes of carbon accounting. Most corporations report only on scope 1 or scope 2 carbon emissions when they account for the company's environmental impacts. The carbon emissions related to Tier 2 or 3 suppliers during the distribution, transportation, use and disposal of a product remain unaccounted for. These

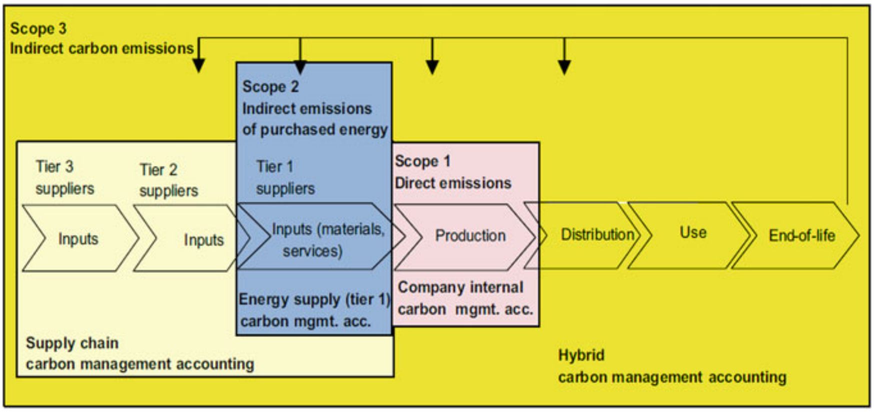

Fig. 1 Scopes of corporate carbon accounting. *Source* Schaltegger and Csutora (2012)

indirect impacts are, however, highly significant, especially with long supply chain industries. Research by Matthews et al. (2008) has confirmed that the most cost-effective carbon mitigation strategies cannot be applied if scope 3 emissions remain undisclosed and unmanaged. Estimates by Huang et al. (2009b) suggest that scope 3 emissions could account for up to 75 % of the total GHG emissions of a company. Dasaklis and Pappis (2013) provided an overview of the challenges supply chain management has to face in the future and showed possible responses from companies. This included accounting for indirect GHG emissions throughout the supply chain.

Different accounting schemes exist to measure the emissions of companies. The Greenhouse Gas Protocol Corporate Accounting and Reporting Standard is one of the most widely-accepted and widely-used accounting systems that is applied to companies' greenhouse gas emissions (GHG).

The Greenhouse Gas Protocol is a market-based voluntary tool comprised of three components: standards, guidelines and calculation tools. It assists companies and other organizations in preparing a GHG emissions inventory and accounting for scope 3 emissions (Gaussin et al. 2013). The aim is to convince the investors and companies to account for their indirect emissions. The methodological guide of the GHG Protocol includes a guidance for calculating scope 3 emissions. Default emission factors are included based on extensive data sets and they are mostly identical to the emission factors used by the IPCC. The GHG Protocol has become a standard for physical carbon accounting for organisations and is both the basis for the GRI (Global Reporting Initiative) and the CDP (Carbon Disclosure Project; see later) (World Business Council for Sustainable Development and World Resources Institute 2004). The CDP is designed to account for the energy use and GHG emissions of companies to improve company management of greenhouse gas emissions and to get reduction targets integrated into corporate strategy. The standards of the CDP have been developed to provide transparency and comparability in accounting. The scheme provides information for institutional investors as well.

Downie and Stubbs (2013) suggest that industrial sectors need more detailed and comprehensive guidance about the relevant emissions that should be included in scope 3. The GHG Protocol defines guidelines for industries like the oil industry, power plants, the paper and pulp industry, etc., but for other economic sectors more guidance is still needed. An exploratory study by Downie and Stubbs (2013) showed that there is wide disparity in which emission sources are included in accounting processes. The authors identified cases where from 2 to 13 emission sources were included, and the accounting methodology varied from using national or regional emission factors to CO_2 per dollar equivalents. Using expenditure is also a popular way to measure a company's emission generating activity. However, the authors concluded that sometimes even using an emission factor in combination with reliable activity data does not necessarily result in reliable identification of the source of emissions, thus there may well be cases when such emissions are not included in accounting processes.

More and more companies have started to use the accounting scheme of the GHG Protocol and empirical results confirm that there is a great need for accounting for scope 3 emissions. The use of hybrid input-output tables is recommended in the methodological guide of the Protocol. In the section that now follows, an overview of empirical findings connected to scope 3 accounting is presented. Literature was selected with the aim to prove the importance of scope 3 accounting for companies.

Lenzen (2002) has already pointed out the need to include indirect impacts in accounting when applying the hybrid lifecycle assessment approach to Australian industrial sectors. Junnila (2006) used hybrid accounting to evaluate the impacts of service sector based companies (e.g. banking and consulting) and the impact of other office supplies (i.e., pencils, erasers, etc.) in Europe and the US. Results indicate that including indirect impacts in an analysis allows the drawing of more precise conclusions and makes scenarios for management options more complete. The climate change impacts of companies from the service sector can be as great as those of manufacturing companies if indirect impacts are accounted for (Rosenblum et al. 2000). Structural interdependencies need to be taken into account, as research by Settanni et al. (2011) confirms. These authors used input-output tables to incorporate the environmental costs of manufacturing systems and used an input-output model for life-cycle costing.

Research has been done to identify scope 3 emissions in industry GHG accounting (Higgs et al. 2009; Hillman and Ramaswami 2010; Huang et al. 2009a; Steuer 2010). Huang et al. (2009a) combined input-output and LCA methods to investigate electronics manufacturing and computer services. Results showed that scope 3 emissions should not be ignored; most emissions are not scope 1 but are emissions embodied in materials and other components. One of the aims of the analysis was to generate information for other companies in the same sector about which activities they should focus their scope 3 emission reduction efforts on.

Pellegrino and Lodhia (2012) examined the disclosure strategies for carbon accounting at an industry level, presenting a case study of the Australian mining industry. Their research suggests that disclosure can be a very useful tool for communicating environmental targets. Presently, accounting systems do not provide enough motivation and targets are often not met. Sullivan and Gouldson (2012) came to the conclusion that, despite the large number of companies that are taking part in the CDP, investors still criticise companies for not providing enough information about their investment decisions. Current reporting processes do not meet the needs of investors who cannot fully assess the risks of emissions from the supply chain, and cannot evaluate the financial costs and risks of reduction strategies. The quality of reporting should thus be improved so that investors are more motivated to take action to reduce emissions (Sullivan and Gouldson 2012). Sanchez et al. (2010) claimed that a company's GHG estimates may be distorted if only scope 1 and scope 2 emissions are accounted for, as scope 3 emissions can comprise a significant share of the total GHG emissions caused by the activity of a company. A better carbon accounting methodology that is able to identify both direct and indirect impacts which emerge through the supply chain is needed. By identifying scope 3, indirect impacts a company could get a more complete picture of its impacts. This would increase transparency for shareholders and help decrease energy use. Moreover, full climate accounting information could be an important criterion for choosing and evaluating a company's suppliers. Ascui (2014) argued that there is considerable potential to integrate and broaden the different types of carbon accounting principles.

This section has proven that it is of utmost importance for companies to account for their scope 3 emissions. Empirical results were reviewed which the magnitude of direct and indirect emissions within the economic sectors. A proper methodology is needed that is able to capture all scopes of indirect emissions and it can be easily used by the companies at the same time. Accounting for direct and indirect emissions may move beyond country borders as well, so the problem of accounting for embodied indirect emissions is present.

3 Allocating Carbon Emissions Between Countries

Accounting for indirect carbon emissions between countries is also of increasing importance. Current environmental policies and obligations (such as the Kyoto Protocol) are framed in such a way that it is possible for Annex I (mostly industrialised) countries to move towards meeting their domestic and international carbon-related commitments by shifting their carbon-intensive industries overseas and relying on growth in international trade to meet the expectations and demands of their consumers. Annex I countries are countries of the OECD and economies in transition who have commitment to reduce individually or jointly the GHG emissions. According to the United Nations Framework Convention on Climate Change (UNFCCC) and National Emission Inventories (NEI), countries must use production-based accounting techniques (Peters 2008). This means that only domestically-produced carbon emissions and greenhouse gases (GHGs) need be accounted for, while imported (demand-driven) GHGs must not be included in national emission quotas and targets. Consequently, the production-related emissions associated with a product that is consumed (for example) in a Western European country but produced in an emerging country will be counted as part of the total emissions of the emerging country which produces them, even though that product was made to meet demand from outside its national borders. Similarly, the emissions associated with products which are exported from Western industrialized countries will appear in the national emission inventories of those countries, although the exported product may be made to satisfy consumer demand in another country. The drawback of this approach concerns the issue raised above: production-based emissions are defined as being all the greenhouse gas that is emitted within national borders.

Much scientific research has concluded that the emission allocation methodology which is applied in climate policy should take indirect GHG emissions into account (Barett et al. 2013; Bastianoni et al. 2004; Davis et al. 2011; Droege 2011; Ferng 2003; Gallego and Lenzen 2005; Rodrigues et al. 2006; Sinden et al. 2011; Wiedmann et al. 2007; Wiedmann 2009). Indirect emissions are emissions that are produced as a consequence of production-related activity, but which arise from different sources (such as transport-related activities, production of purchased materials, outsourced activities, waste disposal, etc.). The consumption-based responsibility and allocation approach includes the emissions of imported products (directly or indirectly) for final domestic demand. This is presumably why a consumption-based approach has become more widespread both in science and in policy. Embodied GHG emissions are often referred to as the carbon footprint of an economic sector or country, though this term has various meanings in the climate accounting literature (Stechemesser and Guenther 2012).

Peters (2008) has argued that a consumption-based approach is an important tool for climate policy and mitigation, being consistent both with the current logic of international trade and with national consumption. The use of consumption-based inventories could have benefits such as including more global emissions with limited participation, increasing mitigation options, encouraging cleaner production (Peters 2008) and perhaps supporting the uptake of environmental policies such as the Clean Development Mechanism (CDM) (Peters and Hertwich 2008). The disadvantages of a consumption-based allocation approach are that the emission calculation process is more complex, which is why critics have claimed that it would increase uncertainty (Barett et al. 2013; Lenzen et al. 2010). Furthermore, a substantive criticism is that it is not solely the final consumer who enjoys the benefits of traded goods, but also the producer (and the producer country). A consumption-based approach may overburden final consumers as they are allocated full responsibility for product emissions. In parallel, the responsibility of producing countries is mostly overlooked. For most European and North-American countries, using a consumption-based approach to GHG emissions would result in them having significantly greater emissions than if using a production-based approach. The opposite is true for China and for other emerging countries with significant export activity.

This section has illustrated the problem of accounting for indirect emissions over the country borders and was relevant to include in the present analysis as China as a producer country is mainly based on export-oriented growth and accounting for embodied emissions in exported products of companies' is highly relevant. The next section shows that case of China and the empirical results in detail.

4 Embodied Carbon Emissions in Chinese Sectors

4.1 The Example of China

The economy of China has developed rapidly over the last few years and the country has become an influential player in the world economy. Labour costs are relatively low and the economy is based on export-oriented growth. Exports are responsible for an increasing share of Chinese GDP. Chinese products are exported from almost all economic sectors. China is significant both in terms of its impact on the world economy and its impact on the global environment. The EU is one of the most important markets for China, and this orientation is gaining in importance. Economic development and increasing levels of production have resulted in growth is GHG emissions, China being responsible for a major part of such increases in these past few years (World Resource Institute 2013). China's national GHG emissions almost doubled between 2002 and 2007, meaning that China has now become the world's biggest emitter of GHGs (Gregg et al. 2008).

Accounting for scope 3 emissions in China is getting more and more important. Liu et al. (2012) presented an analysis of scope 1 and scope 2 emissions in four big cities of China. GHG emissions were mainly generated from the energy use in industrial sector and coal-burning thermal power plants, while scope 2 emissions were from imported products and imported energy use, showing the growing energy dependence of cities. All four cities together discharged about 700 million tons of CO_2 equivalents per year, more than the total emission amount of the UK's emissions. According to Wang et al. (2014) the carbon intensity of economic sectors has dropped in case of many industries from 2002 to 2007, which is an obvious declining trend for the manufacturing industries. As territorial differences can be significant, Bai et al. (2014) concluded that responsibility for embodied emissions in China should be applied on a regional basis. Chang (2014) identified the key CO_2 generating sectors which were not significant for the economy, thus the expansion of those sectors (e.g. water production, non-metal mineral products, petroleum processing) should be limited to achieve emission reduction targets. The driving forces of growing carbon emissions is due to the goods and services consumed by final consumers, thus scope 2 indirect emissions have to be accounted for.

The analysis of exporting activity of Chinese industries and their carbon intensity is highly important, as production for exports contributes to a great share of total Chinese emissions. Several pieces of research have estimated the quantity of emissions embodied in China's international trade. Weber and Matthews (2007) concluded that major contributions to total emissions are due to exports of electronics (22 % of total emissions), metal products (13 %), textiles (11 %), and chemical products (10 %). The significant growth in export-related emissions is increasingly due to the export of more advanced products (the figures for export-related emissions were substantially different in 1995: 19 % textiles, 13 % electronics, 12 % machinery, and 10 % chemicals, and 7 % metal products (Weber and Matthews 2007).

Li and Hewitt (2008) studied the China–UK emission trade balance and found that 4 % of China's CO_2 emissions in 2004 came from the production of goods for the UK market. The quantity of CO_2 this entails is greater than the 69 Mt of CO_2 that would be required to manufacture the same goods in the UK, due to the greater relative carbon intensity of Chinese industry. Shui and Harris (2006) raised three interesting points about the environmental effects of US–China trading activities: (1) US CO_2 emissions would increase from 3 to 6 % if the goods imported from China were produced in the US; (2) 7–14 % of China's current CO_2 emissions result from producing exports to supply US consumers; and (3) US-China trade has increased global CO_2 emissions by an estimated 720 million metric tons. The authors conclude that exporting US technology and expertise related to clean production and energy efficiency to China could help in the future to moderate environmental impacts that are created there. Peters and Hertwich (2008) examined the emissions embodied in trade for 87 countries and regions and found that in 2001 China exported 24 % of its CO_2 emissions and imported 7 % of its domestic emissions. Wang and Watson (2008) confirmed these results by also finding that 24 % of Chinese emissions arose through the creation of exports (data refer to 2004). Su and Ang (2014) highlighted how economic growth-driven emissions are increasing in China and pointed out some potential policy implications regarding the impact of a potential consumption-based emission allocation and trading system.

As for the carbon emission reporting activity of Chinese companies, most of the companies report in some from their GHG emissions, though it is not mandatory for them. Chu et al. (2013) found that more larger companies report than smaller ones, as well as high carbon emission industries reported more often than low-impact industries. This phenomenon can be justified by the legitimacy theory, as the more impacted industries are more motivated to mitigate risk and lower the environmental and policy pressure the industry faces. Though there are not so many companies among listed companies in China who disclose their emission data according to the CDP project. It remains fairly difficult to access the overall performance and carbon risk of companies within the country.

The next section presents the methodology applied in the empirical research.

4.2 Methodology

In the research described herein, hybrid input-output methodology is used to account for embodied emissions in Chinese economic sectors and to identify long supply chain industries at sectoral level. Leontief (1936) developed input-output tables in the form of an industry-by-industry matrix and developed this model (1970) in order to evaluate sectoral interdependencies and environmental impacts. The methodology has been later developed to account for the indirect carbon emissions on sectoral and national level (Bicknell 1998; Gallego and Lenzen 2005; Wiedmann et al. 2007; Minx et al. 2011).

A great advantage of the input-output analysis is that it is able to track the transformation of goods through an economy and show the impact of final use as well as the impact of the use of raw materials. It can also capture the impact of goods and services that are exchanged. Using the input-output tables we can identify the embodied impacts along the supply chain, thus real, both direct and indirect impacts caused by the production of economic sectors can be revealed. That is why this method is appropriate to identify the long supply chain industries which require inputs from many other industries and generate indirect impacts along the supply chain. These indirect impacts have not been accounted for and allocated to the 'final consumer' industries so far. Monetary production data of economic sectors are combined with physical environmental accounts to estimate the embodied flows of emissions which cannot be assessed directly. This framework can provide a complete picture about the total emissions generated. The method is able to capture the indirect emissions from intermediate consumption of economic sectors. The input-output model provides a powerful and useful framework for analysing and understanding the complex mechanism that links the economic sectors from an environmental point of view.

The use of hybrid accounting is still not widespread. According to Wiedmann (2009) this might be due to a lack of acceptance and awareness about input-output analysis, though it may be useful for companies as acquiring real emission data from scope 2 and scope 3 emitters may be costly for them.

In the empirical research symmetrical input-output tables from the OECD's STAN Database for Structural Analysis (OECD 2013) were used for the calculations. Structural changes in the Chinese economy have been taken into account. For the period 1995–1999 the symmetrical input-output table from the mid 1990s, for the period 2000–2004 the early 2000 input-output table and for 2005–2009 the mid 2000 input-output table for China were used.

GHG emission statistics published by Eurostat were used, along with data about Chinese emissions taken from Zhang et al. (2011). It was assumed that no technological changes had taken place to affect the Chinese economy in the period under study.

The indirect emissions of economic sectors in China are calculated as the total intensity vector (TIV):

$$TIV = (F)(I - A)^{-1}$$

This vector shows both the direct and indirect impacts of each economic sector in the Chinese economy. It is the ratio of direct and indirect GHG emissions per one unit of national currency spent in China (expressed in this analysis in US dollars). This calculation is the key to analyse the long supply chain industries within a country. It can show the total embodied impact and the greater the value, the higher the embodied impact. In case of long supply chain industries it is more difficult to reduce emissions.

The embodied emissions of imported products were calculated using the following formula, as proposed by Peters (2008):

$$EM_{GHG} = (F)(I - A)^{-1} diag(y)$$

In this equation F stands for a vector, with each element representing the embodied GHG emissions value per unit of industry output in China. F remained constant during the period examined.

$(I - A)^{-1}$ represents the direct and indirect requirement matrix calculated from the symmetrical input-output (industry by industry) tables. This is the so-called Leontief inverse matrix showing the input requirements for one additional unit of output (where it exists). Finally, y is the vector for exports.

Another assumption of the methodology can be mentioned which is the sectoral level of aggregation. The level of aggregation is determined by the input-output tables published by the OECD, but there can be distortions because of the aggregation level. For this Marin et al. (2012) gives a detailed review. This methodology was applied to identify and analyse the long supply chain industries in China.

4.3 Results and Discussion

Both the direct and the indirect emission impacts of economic sectors need to be quantified and analysed in order to assess the sectors' contribution to climate change. Figure 2 shows the total intensity vector of selected Chinese economic sectors, showing direct and indirect GHG emissions per one unit of national currency. It can be seen that there is a great difference between the sectors, and without quantifying indirect impacts the significance of the contributions of sectors would completely change. Sectors with the highest total (direct and indirect) intensities include the 'Other non-metallic mineral products', 'Electricity, gas and water supply' and 'Mining and quarrying' sectors.

Indirect impacts per unit of national currency are highest for the: 'Coke, refined petroleum products and nuclear fuel', 'Rubber and plastics products', 'Electricity,

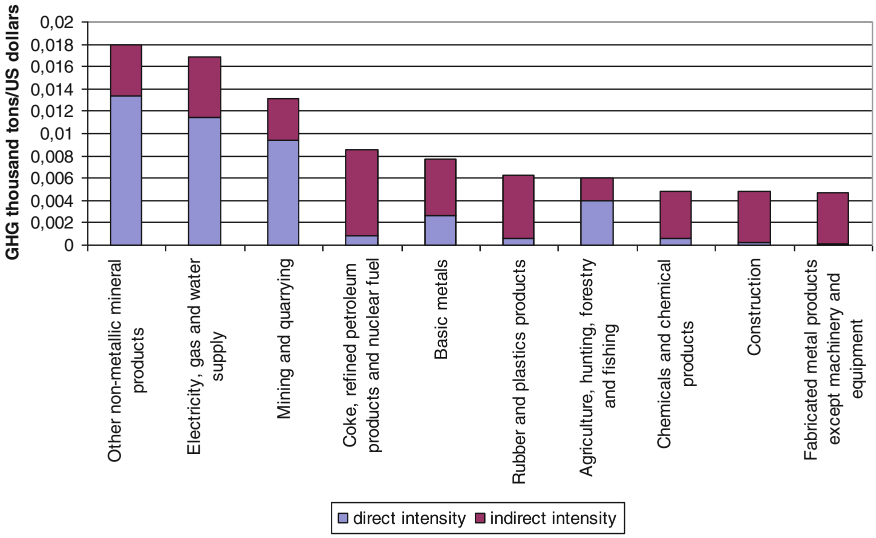

Fig. 2 Direct and indirect GHG intensities of economic sectors in China (top 10 sectors)

gas and water supply', 'Basic metals' and 'Construction' sectors. These sectors require inputs from the mining and quarrying and electricity sectors and they also contribute indirectly to GHG emissions.

The so-called long supply chain industries include: 'Medical, precision and optical instruments', 'Office, accounting and computing machinery', 'Electrical machinery and apparatus n.e.c'. These are the industrial sectors in the Chinese economy that have a relatively long supply chain. With these industries, indirect GHG emission intensities are many times higher than direct emissions (although the total GHG emission contribution of these sectors to the total is not that significant on a national basis). The illustration indicates how accounting for only direct, scope 1 emissions can be misleading. Hybrid carbon accounting may reveal the indirect carbon emissions that are embedded in the supply chains of specific industries. It appears that accounting for indirect emissions in a company's carbon management practices is of utmost importance.

For certain economic sectors in China, indirect impacts contribute less to total impact. The total intensity of embodied carbon is lowest for the economic sectors 'Office, accounting and computing machinery', 'Radio, television and communication equipment', 'Finance and insurance', 'Wholesale and retail trade' and 'Real estate activities'. This is no wonder, as most of these sectors require less material input.

The share of direct impacts is the least in the following sectors: 'Post and telecommunications', 'Basic metals', 'Electricity, gas and water supply' and 'Other non-metallic mineral products'. The reason for this is that the supply chains between the different economic sectors are short. Identifying emissions embodied at different stages of the supply chain may help corporations to formulate achievable reduction targets and meet their emission reduction goals. It is important that carbon reduction strategies focus on reducing the emissions embodied in products which are not consumed in the producer country.

These results are close to the findings of Schulz (2010). In Singapore industries like mineral fuels, lubricants and related materials dominated indirect emissions while recently machinery and transport equipment industries became a more dominant category recently. It was confirmed that iron and steel, non-metallic products, concrete and cement products have high emission intensity in terms of the indirect impacts also in Thailand (Limmeechokchai and Suksuntornsiri 2007).

In the second part of the analysis GHG emissions embodied in products exported from China to the EU-15 were calculated from 1995 to 2009. After this, a sectoral analysis was carried out to reveal how the main export-producing economic sectors contribute to generating direct and indirect emissions.

Figure 3 shows the GHG emissions embodied in exported products along with the total value of exports. From 1995, both export value and embodied emissions in exported products from China to the EU-15 increased significantly. The volume of embodied emissions increased more than ten times. Embodied emissions are accounted for according to the place they were generated, China, though they are generated there due to the demand for products in Europe. According to the production-based accounting approach, emissions within the EU-15 were fairly stable between 1995 and 2005, while after 2005 they started to decrease (EEA 2012). The reason for this was not a decrease in the consumption of the EU-15 countries but rather the delocalisation of production to emerging countries. The increase in number and value of imported products and imported embodied emissions is confirmed by this analysis.

Economic sectors in China were analysed in the context of international trade, as the production of goods for export contributes significantly to total Chinese emissions. Embodied emissions were analysed at a sectoral level in order to reveal the industries which contribute significantly to GHG emissions in China. Structural changes have affected the level of carbon emissions during the last twenty years.

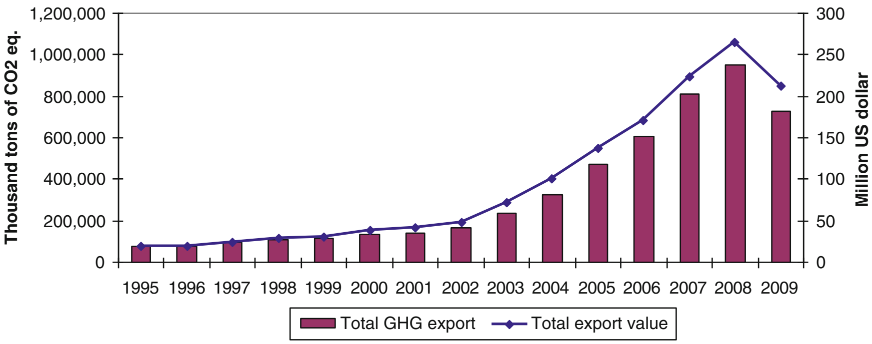

Fig. 3 Embodied GHG emissions in exports from China to the EU-15

Table 1 Embodied emissions in Chinese exports

1995	Thousand tons of GHG
Textiles, textile products, leather and footwear	16,189
Chemicals and chemical products	9946
Other non-metallic mineral products	7029
Basic metals	5525
Manufacturing n.e.c; recycling	4812
2000	Thousand tons of GHG
Textiles, textile products, leather and footwear	23,797
Other non-metallic mineral products	12,661
Chemicals and chemical products	11,981
Machinery and equipment n.e.c	11,638
Office, accounting and computing machinery	8890
2005	Thousand tons of GHG
Textiles, textile products, leather and footwear	71,901
Office, accounting and computing machinery	65,984
Machinery and equipment n.e.c	42,750
Other non-metallic mineral products	39,318
Radio, television and communication equipment	37,385
2009	Thousand tons of GHG
Textiles, textile products, leather and footwear	132,167
Machinery and equipment n.e.c	79,443
Office, accounting and computing machinery	79,018
Other non-metallic mineral products	65,180
Radio, television and communication equipment	54,805

The five most significant economic sectors

Changes in the structure of exports (from China to the EU-15) and embodied GHG emissions were analysed between 1995 and 2009. Table 1 illustrates the economic sectors with the highest embodied emissions in 1995. The ‘Textile, textile products, leather and footwear’ sector exported the highest share of total embodied emissions from China to the EU-15. The supply chain of this sector is relatively long. This sector is followed by the ‘Chemicals and chemical products’ sector and the ‘Other non-metallic mineral products’ sectors, where indirect emissions are also significant and where embodied emissions have grown significantly during the past years. The textile industry also accounted for the highest share of total embodied emissions in 2009 as well, though the volume of emissions has increased more than ten times. This underlines the importance of accounting for indirect impacts.

The ‘Chemicals and chemical products’ industry accounted for 13.2 % of total embodied emissions, though in 2009 this figure was only 6.8 %, so it is not one of the top five industries in terms of having the highest embodied GHG emissions from exported products. The ‘Other non-metallic mineral products’ sector is included in the analysed period in Table 2 where it can be seen that embodied

Table 2 Growth of indirect embodied emissions in export-producing economic sectors in China (1995 = 100 %)

Economic sectors	2000 (%)	2005 (%)	2009 (%)
Textiles, textile products, leather and footwear	147	444	816
Other non-metallic mineral products	180	559	927
Machinery and equipment n.e.c	281	1034	1921
Office, accounting and computing machinery	426	3159	3783
Radio, television and communication equipment	321	1383	2027

emissions grew more than nine times between 1995 and 2009. Table 2 shows the growth of indirect emissions for the major economic sectors where production for exported products is significant.

From 2005, industry sectors such as 'Radio, television and communication equipment' and 'Machinery and equipment n.e.c' created a significant share of embodied emissions. The former contributed 10.9 % of total embodied emissions in 2009, though in 1195 this was only 5.5 %.

These empirical results can be compared to other recent studies on Chinese embodied emissions. Results of Yang and Chen (2014) stressed that, cement production is one of the largest carbon emission sources in China. The electricity industry is of course the largest emitter of direct carbon emissions. In China, exporting sectors with high embodied carbon are the smelting and pressing of metals, accounting for 25.19 % of the total emissions in exports, followed by sector nonmetal mineral products, 15.07 %, and the chemical industry (15.07 %). Exports concentrated mostly on primary energy intensive sectors. From a supply-chain perspective, only a small part of the embodied CO_2 emissions were captured by these sectors. It is important to note that these results referred to all exports, while data analysed in the present chapter focused on emissions embodied in exports to the EU-15, so the structure of the exports may be different. Transforming the current export structure of Chinese industries from energy intensive sectors to high-tech manufactory industries (for example communication equipment, computers and other electronic equipment) may be a possible way to decrease CO_2 emissions embodied in exports.

5 Conclusions

As companies are part of supply chains they should be aware that their activities may affect emissions in other economic sectors. The long supply chain industries where it is highly important to reveal and account for scope 3 emissions need to be identified.

The article has contributed to emission accounting literature as it reviewed the key aspects in accounting for scope 3 emissions. The review of previous literature has shown that in scientific circles it is already accepted that accounting for indirect scope 2 and 3 emissions is essential. Previous empirical results have shown that more and more companies try to integrate GHG accounting and reporting to their management practices. To integrate indirect emission reporting to companies, proper methodological tools and guidelines are needed. Disclosure standards at the corporate level should be developed and companies should also engage in working out carbon reduction strategies and acknowledge the significance of disclosing corporate carbon information.

Relevant literature regarding scope 3 emissions in China were summarised as well. In China there is a growing pressure to mitigate and account for GHG emissions, a great proportion of these are due to indirect, embodied emissions. The empirical findings of this paper examined direct and indirect emission intensities in Chinese economic sectors. Furthermore, the focus was on those specific economic sectors which contribute significantly to total Chinese emissions due to their great share of exports. Empirical data confirmed that there are certain economic sectors where it is highly important to account for scope 2 and scope 3 indirect emissions. It is also important to recognise that economic sectors often have completely different material input needs and thus accounting for scope 3 emissions is not equally important for all sectors. Climate change may have significant impacts on the business activities of corporations, creating internal and external costs and benefits. Companies need to respond to this challenge properly and become more motivated to account not only for the direct but also for the indirect emissions of their production activities. Long supply chain industries should become the focus of carbon accounting, especially those which are major exporters. Controlling the expansion of high intensity and long supply chain industries is needed. Furthermore minimizing material inputs and shortening unnecessary supply chains to sector-level production are also efficient ways to reduce indirect emissions. This point is specifically important for sectors with long supply chains.

The example of Chinese economic sectors described in this paper showed that hybrid input-output accounting can be a useful tool to identify and highlight economic sectors where embodied carbon emissions are significant, and to identify long supply chain industries. The likely future sources and drivers of carbon-related impact need to be analysed further. More detailed analysis of aggregated economic sectors is particularly needed.

Several implications of the present research can be summarised which can be useful for management practices. Managing the upstream and downstream consequences of carbon emissions is critical for reducing carbon related input and GHG emission risks. The results of carbon accounting for direct and indirect emissions may be a highly important factor when evaluating company performance. Carbon accounts can help corporate leaders to develop scenarios and to identify what the main sources and drivers of carbon impacts could be in the future. This information will also benefit corporations, consumers and investors through reducing information asymmetry and increasing the transparency of the company's emission accounting (Matisoff 2013). Analysing corporate level scope 3 emissions can also be used to highlight examples of companies that have already reduced their emissions as a result of accounting for their indirect impacts. The methodology presented can be used to measure carbon performance both in the production process as well as in the supply chain. It can also help companies to choose their suppliers based on the carbon intensity. This can help to expand low-impact supply chains in the economy and to re-configure the supply chain networks. Rationalizing supply chains may be a source of cost-saving as well. When key sources of indirect emissions are known, the carbon intensity of suppliers (that contribute to indirect emissions) may become an important criterion for companies when choosing suppliers. Supply chain partners should become more aware of the fact that not only scope 1 but scope 3 emissions are generated by production activities and that companies and industries have responsibilities that extend beyond their organisational borders.

A firm's carbon management strategy and carbon performance measurement can provide useful quantified information for corporate decision makers. Investors can be more informed when making decisions related to the production processes and environmental impact of companies. Combination of direct emission data with the indirect or embodied emissions may provide a picture of total emissions discharged. This way the impact of future environmental legislation and changes in cost for the manufacturer can be forecasted in a carbon-constrained world. Managers should be more motivated to collect and use carbon-related information. Carbon management could be integrated to mainstream management practices. Hybrid accounting may serve as a good framework for companies to estimate and account for their scope 2 and scope 3 emissions.

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Voluntary Greenhouse Gas Reporting: A Matter of Timing?

Nele Glienke

Abstract Private sector action is perceived to be a major source for climate change mitigation and climate change-related data is a major source of information for the involved stakeholder groups. In this article, I investigate the timing of voluntary greenhouse gas (GHG) reporting and corporate stakeholder orientations. To this end, I analyze corporate participation in the best known voluntary initiative in this context, the Carbon Disclosure Project (CDP) at two points in time. These are at the beginning of the CDP in 2003 and once the initiative is a globally institutionalized practice in 2011. I use multinominal logistic regression analysis and focus on corporations listed in the FTSE Global 500 index between 2003 and 2013 (n = 270). These are classified into corporations that started participating early versus those that started participating late. More than half of the corporations in my sample are categorized as early participants. The results of my analysis show that CDP participation is linked to different stakeholder orientations depending on its timing. In 2003, by participating in the CDP right from its start, corporations satisfy the claims of legislature and civil society. In 2011, by participating in the CDP once the initiative is a globally institutionalized practice, corporations satisfy the claims of investors and final consumers. Empirical research on voluntary GHG reporting examines its factors of influence. However, the timing of voluntary GHG reporting and the related stakeholder orientations are not in the focus of the literature. The present analysis elaborates on these issues and suggests recommendations for future research.

1 Introduction

The first report of the Intergovernmental Panel on Climate Change (1990: 11) stated that "emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases … These increases will

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enhance the greenhouse effect, resulting on average in an additional warming of the Earth's surface." More than two decades after this assertion, the emission of greenhouse gases (GHG) into the global atmosphere through the burning of fossil fuels is with a high probability the major contributor to global climate change (Intergovernmental Panel on Climate Change 2013). It is influencing the regulating services of the global atmosphere in a negative way and overcharging the carrying capacity of the earth (Carroll and Hannan 1995; Meadows et al. 1972). At present, climate change has already passed its planetary limits (Rockstroem et al. 2009).

In the debate about man-made climate change, the private sector proves critical for two reasons. Firstly, corporate industrial activity is the main source of climate change, contributing to the changing global climate via the direct emission of GHG in production processes as well as via the indirect emission of GHG that arises along the value chain (Porter and Reinhardt 2007). This subsequently results in the fact that, secondly, private sector action is perceived to be a major source for climate change mitigation. In this context, climate change-related data is a major source of information for investors, policy makers and the general public in order to assess and compare corporate performances (Andrew and Cortese 2011; Busch and Hoffmann 2011; Kolk et al. 2008; Matisoff et al. 2013; Stanny 2013). As a result, the voluntary reporting of climate change-related information has risen strongly on the agenda of corporate decision makers and increasingly comes into focus of researchers and policy makers alike.

The empirical literature on the voluntary reporting of GHG emissions (voluntary GHG reporting hereafter) examines firstly the amount and quality of information disclosed in corporate advertisements, on corporate websites, in annual, environmental and sustainability reports and to voluntary initiatives. Secondly, it targets corporate engagement in voluntary GHG initiatives, such as participation in the Carbon Disclosure Project (CDP), the Canadian Voluntary Climate Challenge and Registry (VCR) and several programs launched by US governmental bodies.

In sum, this research agrees on a significant positive influence of a number of internal factors, including size (Clark and Crawford 2012; Rankin et al. 2011), profitability (Prado-Lorenzo and García-Sánchez 2010; Ziegler et al. 2011), environmental performance (Brouhle and Ramirez-Harrington 2010; Welch et al. 2000), media visibility (Berthelot and Robert 2011; Dawkins and Fraas 2011), shareholder pressure (Reid and Toffel 2009) and multinational scope (Stanny and Ely 2008; Stanny 2013). Furthermore, corporate environmental reporting behaviour can be differentiated by industry (Amran et al. 2011; Freedman and Jaggi 2005; Moon 2008) and region (Brouhle and Ramirez-Harrington 2009; Luo et al. 2012).

To the best of my knowledge, this stream of literature examines the factors of influence for voluntary GHG reporting but not the timing of voluntary GHG reporting. Regarding voluntary GHG reporting over time, Matisoff et al. (2013) find improvements in the reporting of GHG emission amounts to the CDP from 2003 to 2010 but criticize insufficient external verification of the data. The logistic regression results of Stanny (2013) suggest that answering the CDP questionnaire has increased from 2006 to 2008 for US corporations. Those that previously answered the questionnaire have been found more likely to participate in the following years. Interestingly, the author explains the ambiguous results regarding the regulatory proxies with the suggestion that "firms that disclose in earlier CDPs disclose for different reasons than those that disclosed in later ones" (Stanny 2013: 155). She points to the need to investigate this phenomenon in more detail. Thus, answering her call for research and contributing to the above cited research, I investigate the timing of voluntary GHG reporting.

2 Theories on Voluntary Reporting

Socio-political theories conceive the voluntary reporting of corporate information as a function of social and political pressures in an organization's business environment (Gray et al. 1995). They can be differentiated into three overlapping theories which are stakeholder theory, legitimacy theory and political-economy theory (Gray et al. 1995; Patten 2002).

I begin with stakeholder theory as it manifests the largest overlap with the other theories. Stakeholders (Freeman 1984) include all actors relevant for a company's strategy and the direct achievement of its objectives (Dill 1958). As they control critical resources (Frooman 1999; Jacobs 1974; Lawrence and Lorsch 1967; Pfeffer and Salancik 1978), they are in the situation to exert pressures on corporations to report information (Clarkson 1995). These pressures are perceived and treated differently by corporate decision makers, depending on internal corporate characteristics (Delmas and Toffel 2004). Stakeholders often hold opposing or conflicting demands regarding environmental protection issues (Buysse and Verbeke 2003; Delmas and Toffel 2004; Hart and Sharma 2004; Rueda-Manzanares et al. 2008; Sharma and Henriques 2005) that have to be reconciled. Because these are often opposed to economic interests (Rugman and Verbeke 1998), a profit-driven organization only attends those environmental claims that involve salient stakeholders (Mitchell et al. 1997) and thus are linked with economic consequences (Starik and Rands 1995).

Stakeholder groups can be differentiated into regulatory, primary and secondary stakeholders (Buysse and Verbeke 2003). Regulatory stakeholders involve local, national and global regulatory agencies. They have the ability to halt or hamper corporate operations on the grounds of insufficient compliance with environmental standards (Buysse and Verbeke 2003). Primary stakeholders are situated in the corporate market environment and maintain formal relationships with corporations, i.e. contracts of employment and monetary funding as well as customer relationships. Their claims directly compromise uncertain and critical production factors needed in order to achieve long-term corporate success (Freeman 1994; Jacobs 1974; Lawrence and Lorsch 1967; Pfeffer and Salancik 1978). Secondary stakeholders, such as the media, NGOs or competitors, indirectly influence a corporation's long-term success through informal relationships (Clarkson 1995; Henriques and Sadorsky 1996). They have a strong influence on public perceptions of what is acceptable corporate behaviour, the corporate legitimacy. Corporate decision makers need to accommodate secondary stakeholders' claims in order to keep their 'license to operate' (Bozeman 1987; Meyer and Rowan 1977; Powell and DiMaggio 1991). On this account, they engage in the voluntary reporting of non-financial information (Deegan 2002).[1]

Legitimacy theory has a large overlap with stakeholder theory as it focusses on one specific stakeholder group, namely secondary stakeholders or civil society (Boesso and Kumar 2007). From this perspective, organizations strive to accommodate the pressures exercised by civil society to achieve social legitimacy (Meyer and Rowan 1977; Powell and DiMaggio 1991). Public perception of corporate legitimacy is in constant evolution (Lindblom 1994). Thus, corporate legitimacy is always endangered when public perception of what is acceptable corporate behaviour changes. This might be linked with particular events calling into question the legitimacy of a specific corporation or industry sector (Patten 1992).

According to legitimacy theory, information is instrumental for changes in public perceptions to bridge the gap between what is publicly accepted corporate behaviour and how a corporation is perceived by the public (Cormier and Gordon 2001; Dowling and Pfeffer 1975; Patten 1992). Public perceptions of corporate legitimacy are thus perceived as modifiable by corporate decision makers through the use of voluntary reporting (Deegan 2002) and corporate decision makers voluntarily adopt the practice to report non-financial information to socially legitimize their operations. Several communication strategies have been proposed for corporations to maintain corporate legitimacy. A corporation can either try to change external perceptions of legitimacy through use of disclosures, employ disclosures to direct public attention away from a certain critical issue, or change its disclosures to fit with external perceptions of legitimacy (Dowling and Pfeffer 1975; Lindblom 1994).

Political economy theory has large overlaps with stakeholder and legitimacy theory. This theory focuses on the exchanges of power between the economic system and the larger political, social and institutional framework (Gray et al. 1995). It examines the interplay between structural and regulative institutions at the national level and organizational structure and functions (Tempel and Walgenbach 2007). In short, political economy theory specializes on another specific stakeholder group, namely regulatory stakeholders or legislature.

In this context, a Marxian interpretation and a bourgeois interpretation of political economy theory can be differentiated (Gray et al. 1995). The Marxian interpretation of political economy focuses on class interests and structural inequities within the productive economic system that conflict with the government (Abercrombie et al. 1984). By contrast, in the bourgeois interpretation of political economy theory, the reconciliation of a pluralism of social and political interest groups by the productive economic system is at the heart of the analysis (Arnold 1990).

From the perspective of economics based voluntary reporting theories, the voluntary reporting of corporate information is characterized by information

[1]This is a theoretical ideal distinction. In practice, the boundaries between different stakeholder groups, especially between primary and secondary stakeholders, are not always sharp.

asymmetry and adverse selection (Akerlof 1970; Spence 1973): A corporation (the agent) possesses more information than its stakeholders (the principal). According to these theories, the agent's reporting behaviour results from an optimization of the related costs and benefits, assuming a fixed reaction of the principal (Verrecchia 2001). Economics based voluntary reporting theories can be further differentiated into information and proprietary cost theory (Verrecchia 2001).

Information cost theory assumes that corporate decision makers take into account the costs of publication and dissemination when taking their decision to voluntary report any non-financial information. According to this theory, the costs of publishing and disseminating non-financial information are decreasing with corporate size (Diamond 1985). Furthermore, good performing corporations report more non-financial information because they value the potential benefit of a proactive image higher than the potential information costs (Lang and Lundholm 1993).

Proprietary cost theory further elaborates the information cost theory by including propriety costs into corporate decision maker's profit maximization. Propriety costs involve those costs that are "associated with disclosing information which may be proprietary in nature, and therefore potentially damaging" (Verrecchia 1983: 181).

In sum, the theories cited above conceive voluntary reporting of corporate information either as dependent on the external expectations and pressures exerted by different stakeholder groups (socio-political theories) or as dependent on the internal payoff related to voluntarily disclosing any information (economics based theories). I will now analyse the empirical evidence of voluntary environmental reporting regarding its fit with these two theories.

3 Evidence of Voluntary Environmental Reporting

The voluntary reporting of environmental information is largely analysed from a socio-political (and especially legitimacy) perspective (cf. Clarkson et al. 2008; Darrell and Schwartz 1997; Deegan et al. 2002; Patten 2002; Reid and Toffel 2009; Stanny 2013) while economics based theories of reporting only play a minor role (cf. Jira and Toffel 2013). Current research finds that corporations are more likely to participate in voluntary environmental initiatives and report more and higher-quality environmental information when faced with higher scrutiny by legislature, civil society, investors and final consumers. I will detail this evidence in the following.

3.1 Scrutiny by Legislature

Because of expected and existing environmental regulations, corporations have been repeatedly found to adopt proactive environmental management practices in general (Delmas 2002; Majumdar and Marcus 2001; Rugman et al. 1997; Rugman and Verbeke 1998) and environmental reporting in particular (Clarkson 1995; Patten 2002). GHG regulation has been found to promote corporate efforts to mitigate climate change (Hoffman 2007; Porter and Reinhardt 2007), with the Kyoto Protocol (UNFCCC 1997) being the most common example. Differing GHG regulations in the US and EU have repeatedly been identified as the main cause for differences in corporate action on climate change. Skjærseth and Skodvin (2001) trace the reactive stance of the US oil industry back to a lack of regulative pressure to reduce emissions. Levy and Rothenberg (2002) identify a considerable difference between the climate change responsiveness of car manufacturers in the EU and in the US, where regulation of vehicle emissions is less pronounced.

As regards voluntary GHG reporting, European policymakers are at present working on binding rules for the reporting of non-financial information (Council of the European Union 2014; European Commission 2011). Binding reporting requirements already exist for those installations subject to the European Emissions Trading Scheme (European Community 2009). In the US, mandatory reporting requirements of potential negative impacts from climate change target corporations subject to the supervision of the US Securities and Exchange Commission (SEC) (SEC 2010). So far, common agreement exists on a promoting influence of stringent environmental regulation. Globally, a corporation's home country Kyoto Protocol ratification is suggested to enhance voluntary GHG reporting (Freedman and Jaggi 2005; Gallego-Álvarez et al. 2011; Prado-Lorenzo et al. 2009). Furthermore, GHG reporting is also promoted by environmental regulation at the national (Luo et al. 2012; Reid and Toffel 2009) and corporate level (Stanny 2013; Welch et al. 2000). For example, Brouhle and Harrington (2009) analyse participation in the VCR, a voluntary regime encouraging the reporting of GHG emissions, the establishment of mitigation targets and their accomplishment in Canada. They find an overall improved involvement across federal provinces and sectors over time. This is suggested to be linked to Canada's ratification of the Kyoto Protocol in 2002. Stanny's (2013) results suggest that the publication of the CDP questionnaire has largely increased from 2006 to 2008 for US corporations (Stanny 2013), a time period when a political discussion regarding mandatory GHG reporting requirements in the US was in full swing.

3.2 *Scrutiny by Civil Society*

Empirically, corporate reporting of environmental and social information has frequently been linked with the intention to receive social legitimacy (e.g. Darrell and Schwartz 1997; Deegan et al. 2002; Patten 1992). The rise in public attention to global environmental problems has been linked to an increase in proactive environmental management practices (Aerts et al. 2008; Dunlap and van Liere 1978; Hilgartner and Bosk 1988) as the general public pressures the government to create new regulations or strengthen existing ones (O'Dwyer 2002). In this context, voluntary reporting of environmental and social information is employed by corporate decision makers to gain or increase corporate legitimacy (Cormier et al. 2005; Darrell and Schwartz 1997; Deegan et al. 2002; Frost 2007; Nikolaeva and Bicho 2011; Patten 1992). For example, Patten (1992) finds that, after the Exxon Valdez oil spill, the voluntary reporting of environmental information of the petroleum industry greatly strengthened due to increased public interest.

As to voluntary GHG reporting, Dawkins and Fraas (2011) show that visibility, measured via media visibility of the corporation in general as well as regarding climate change issues in particular, promotes CDP participation. Welch et al. (2000) reveal that US corporations headquartered in states with high levels of environmentalism are more likely to volunteer in the US Climate Challenge program. Finally, previous engagement in a voluntary GHG initiative positively influences future engagement which is linked to corporate concerns of social legitimacy (Brouhle and Ramirez-Harrington 2010; Stanny and Ely 2008; Stanny 2013).

3.3 Scrutiny by Investors

Lenders and investors are also hypothesized to foster the adoption of new environmental practices (Funk 2003; Weber et al. 2010) and enhance voluntary reporting of non-financial information (Bushee and Noe 2000). Stock markets positively evaluate corporations with a favourable environmental management reputation (Aaron et al. 2012) and those involved in environmental policies (Al-Najjar and Anfimiadou 2012).

Regarding voluntary GHG reporting, Reid and Toffel (2009) find that corporations are more likely to participate in the CDP if they or their competitors have been targeted by climate-change-related shareholder resolutions in the previous year. However, the authors find no relationship between the proportion of shares held by CDP signatories and CDP participation. This reflects earlier results of Stanny and Ely (2008). Research on stock market returns is similarly ambiguous. In an event study, Keele and DeHart (2011) find the announcement of participation in the US Environmental Protection Agency's Climate Leaders program to result in negative stock returns except for on the announcement day. Contrary to this finding, Ziegler et al. (2011) show that the stock performance of EU corporations and US utilities disclosing GHG mitigation measures and a public statement on climate change is higher compared to their non-disclosing counterparts over a six year period.

3.4 Scrutiny by Final Consumers

Corporate market-orientation has been found to result in innovativeness and superior economic performance (Han et al. 1998). If consumers are environmentally sensitive, market-orientation enhances the adoption of new environmental practices

(Yalabik and Fairchild 2012) and is suggested to increase environmental reporting (Ilinitch et al. 1998; Moneva and Llena 2000; Munilla and Miles 2005). In this regard, González-Benito and González-Benito (2008) find that market-oriented industrial corporations are more likely to engage in new environmental practices. Kassinis and Soteriou (2003) provide evidence of a positive relationship between consumer satisfaction and environmental practices in the services industry.

Regarding voluntary GHG reporting, results are more ambiguous. Regression analyses of the relationship between consumer proximity and corporate engagement reveal both, negative (Brouhle and Ramirez-Harrington 2010; Dawkins and Fraas 2011; Stanny and Ely 2008) and positive (Luo et al. 2012) coefficients.

4 Hypotheses Development

Against this empirical background, I take a socio-political perspective on voluntary environmental reporting in the following. In order to develop my research hypotheses on the timing of voluntary GHG reporting, I now analyse the diffusion of corporate practices across corporations, sectors and time.

4.1 The Diffusion of Innovative Corporate Practices

The organizational innovation literature examines one of the key mechanisms in the analysis of organizations, namely the diffusion of innovative corporate practices within and across corporations as well as across time (Davis and Marquis 2005).[2] It can be differentiated into three separate streams of literature. These include literature on the diffusion of innovations across organizations and time (diffusion of innovation research), on the factors of influence for organizational innovativeness (organizational innovativeness research) and on the stages of innovations within organizations (process theory research) (Wolfe 1994).

The focus of this research is on the innovative practice, namely participation in the CDP. Therefore, I rely on the first stream of literature hereafter, the diffusion of innovation research. This research stream focuses on the innovation itself and analyses its spread within a population of potential adopters—its diffusion (Wolfe 1994). Within diffusion research, there exist two contradicting models, the rational

[2]In theory, a distinction between innovation, i.e. the commercially successful application of a new idea by its developers, and the diffusion of innovations, i.e. the commercially successful application of a new idea beyond its developers, exists. In practice, this differentiation is, however, blurred (Ashford 2002).

model and the sociological model (Ansari et al. 2010). I will look at both in more detail in the following.

Rational models conceive the likelihood of the diffusion of an innovation as a function of its economic benefits (Strang and Macy 2001). The core mechanism in these models is the accumulation of information about the cost effectiveness of an innovative practice by corporate decision makers. Observing early adopters, they continuously update their information about the value of an innovative practice and thus optimize their point of entry (Terlaak and Gong 2008). With rising diffusion rates, the accumulated information about a practice reduces both, uncertainty and search costs related to the innovation which is in turn further speeding up its diffusion process (Ansari et al. 2010). Thus, cost effective innovative practices diffuse faster than less effective practices due to increased imitation.

While rational models are based on the concept of accumulating information about the cost effectiveness of an innovative practice, increasing levels of pressure in the institutional business environment are at the heart of sociological models (Ansari et al. 2010). These models assume that corporations imitate other corporations because they want to keep or increase their social legitimacy (DiMaggio and Powell 1983; Scott 2001). Thus, the diffusion of innovative practices may have little to do with its cost effectiveness or notions of corporate performance (DiMaggio and Powell 1983; Greenwood and Hinings 1996; Meyer and Rowan 1977). Indeed, in its strong form, sociological models conceive the diffusion of an innovative practice as completely independent of its cost effectiveness, such that even ineffective practices may diffuse due to the expectations of stakeholders (Abrahamson 1991; DiMaggio and Powell 1983). The weak form of sociological models assumes that cost effectiveness plays a role in the initial adoption phase (Ansari et al. 2010). However, the more an innovative practice diffuses, the less important become these considerations and the more important becomes the imitation of peers and fashion setters (Tolbert and Zucker 1983).

In sum, the above cited models conceive corporate decision makers either as rationally scanning their business environments for efficient practices that they decide to adapt depending on their internal circumstances (economic mechanisms of diffusion) or as adapting practices that seem to increase social legitimacy, (almost) regardless of their efficiency (strong/weak sociological mechanisms of diffusion). I will now analyse the empirical evidence of the diffusion of environmental practices regarding its fit with these two models.

4.2 Evidence of the Diffusion of Environmental Practices

Regarding the diffusion of corporate environmental management practices, research shows that once there is awareness for and public pressure to reduce environmental degradation, legislature represents the single most important factor of influence for the adoption of corporate practices (cf. Henriques and Sadorsky 1996; Hocking and Power 1993; Rugman and Verbeke 1998). This has been shown in Hoffman's

(1999) longitudinal analysis of corporate environmentalism in the US chemical industry. Bansal (2005: 203) further suggests that at this time, a limited number of "firms may also see the opportunity to generate rents from resources and capabilities because of imperfectly competitive strategic factor markets" (Bansal 2005).

In later years, the professionalization of environmental protection as a corporate responsibility dominates the earlier importance of environmental regulation (Hoffman 1999). As task and institutional environments connect over time, this allows for the diffusion of corporate environmentalism (Jennings and Zandbergen 1995) through the reproduction and development of corporate best practices. This leads to the situation where successful environmental practices are increasingly mimicked because they are recognized as competitively valuable (Jennings and Zandbergen 1995).

Against this background, I base my hypotheses on strong sociological mechanisms of diffusion and argue that voluntary GHG reporting is at no time adopted due to cost efficiency reasons. Instead, corporations participate in the CDP due to pressures exerted by different stakeholder groups to gain or increase social legitimacy. In detail, I hypothesize that corporations were more likely to participate in the CDP at its early days due to legislative pressure and pressure from civil society. By contrast, once the CDP was professionalized, corporations were more likely to participate due to pressures from investors and final consumers. Thus, my hypotheses are as follows:

Hypothesis 1 In 2003, new CDP participants were more likely under pressure to report GHG emissions by legislature than firms that will start participating later.

Hypothesis 2 In 2003, new CDP participants were more likely under pressure to report GHG emissions by civil society than firms that will start participating later.

Hypothesis 3 In 2011, new CDP participants were more likely under pressure to report GHG emissions by investors than firms that have started participating earlier.

Hypothesis 4 In 2011, new CDP participants were more likely under pressure to report GHG emissions by final consumers than firms that have started participating earlier.

5 Data and Method

5.1 Sample

Regarding voluntary GHG reporting, the CDP is accepted worldwide as most relevant because of its large coverage and continuity over time (Kolk et al. 2008; Stanny and Ely 2008). Since 2003, it annually requests climate change-related data of corporations around the globe in the name of government bodies, institutional investors, and purchasing organizations. The CDP questionnaire involves detailed questions on corporate risks and opportunities of climate change as well as conceivable corporate action. Corporate responses are made publicly available on the CDP website in case an organization does not choose to exclude this possibility. Furthermore, responses are summarized in an annual report. In 2013, over 5000 corporations have been requested by the CDP (2013). The initiative is currently supported by 722 investors with assets of 87 trillion US dollars (CDP 2013).

Responding to the CDP has developed into a global trend over the past ten years (Kim and Lyon 2011a; Kolk et al. 2008). Figure 1 provides a graphic exemplification of the rising response rates over time. The black bars depict the percentage of completed questionnaires for the total of corporations listed in the Financial Times Stock Exchange (FTSE) Global 500 index (the Global 500 hereafter) from 2003 to 2013 as published by the CDP. This index includes the 500 largest publicly traded corporations worldwide according to market capitalization in the FTSE Global Equity Index (CDP 2013). Figure 1 shows that response rates have generally increased with the most pronounced rises appearing in 2004 and 2005. The percentage of completed questionnaires first rose above 70 % in 2005. After that, response rates show a steady but less pronounced increase. Finally, in 2009 and

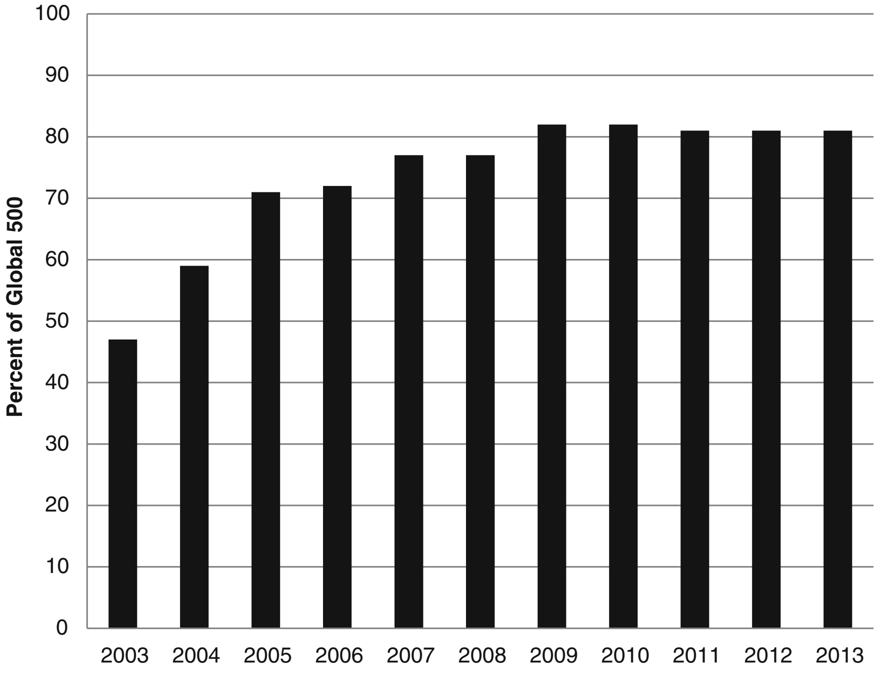

Fig. 1 Response rates of the Global 500 to the CDP from 2003 to 2013

2010 response rates reached 82 %, the highest value up to now. Since 2011, CDP response rates steady at 81 %.

I analyse CDP participation of the Global 500. The sample includes corporations that have been surveyed by CDP within the Global 500 from 2003 to 2013. Changes in corporate ownership have been solved as follows:

- In the case of acquisitions and if the new parent company has been surveyed by the CDP within the Global 500 from 2003 to 2013, the acquired corporation is kept in the sample as a separate observation, along with the parent company.
- In case of partial acquisitions by different corporations, the acquired corporations are excluded from the sample. This involves for example Cendant, Fortis and Lehman Brothers.
- The same approach applies to mergers.
- Corporations that have been transferred to government sponsored organizations are excluded from the sample. This involves for example: ABN AMRO, Fannie Mae and Freddie Mac.

My final sample consists of 270 corporations. Of these, I obtained financial and other information from the Datastream database. All dependent and control variables (except the measure for pressure by legislature as explained below) are lagged one year. Thus I obtained the Datastream data for the years 2002 and 2010.

5.2 Dependent Variable

CDP participation is defined as a public or non-public answer to the CDP. The provision of information other than the completed questionnaire, such as environmental or sustainability reports, is not considered as CDP participation. I classify corporations as early participants if they participated in the first two years of the CDP, i.e. in 2003 and 2004, and continually participated in the CDP up to 2012. Corporations are classified as late participants if they have been surveyed by the CDP within the Global 500 since 2003 and first participated in 2011 and 2012. These years are chosen as a breakpoint to differentiate late participation because this is when response rates slow down among the Global 500, indicating an institutionalization of the CDP (compare Fig. 1).

The categorical variable *participation* takes a value of one for early participants and a value of two for late participants. Regarding corporations that are neither considered early nor late participants, the variable takes a value of zero. These corporations are participating in the CDP irregularly and are therefore called undecided participants.

5.3 Independent Variables

Pressure by legislature. (2005) find that a corporation's home country Kyoto Protocol ratification positively influences voluntary GHG reporting. It can be argued that regional or national regulations represent more accurate measurements for regulatory pressure. However, their scope is often limited while Kyoto Protocol ratification is globally applicable. For example, the European Emissions Trading Scheme covers only airlines and production installations operating in the EU. The mandatory reporting requirements of potential negative impacts from climate change regulation in the US exclusively targets corporations subject to supervision by the SEC.

Since 2006, Germanwatch each year publishes a report on the climate change performance of the top CO_2 emitting countries worldwide with the aim to create a greater understanding of these countries' national and international climate policies (Germanwatch and Climate Action Network 2014). Based on standardized and objective indicators, the authors calculate the so called Climate Change Performance Index (CCPI hereafter). In 2014, the CCPI is based on indicators regarding emissions, energy efficiency and renewable energy as well as "national and international climate policy assessments by more than 250 experts from the respective countries" (Germanwatch and Climate Action Network 2014: 7). Since 2013, emission indicators also consider emissions from deforestation (Germanwatch and Climate Action Network 2013).

Despite the continually improving methodology of the CCPI, I use the data of the first report in 2006, as my analysis of legislative pressures focusses on the time frame 2002/2003 [3]. In this report, the indicators under review were indicators of emission trends and emission levels as well as expert opinion on climate policies. Thus, the ordinal variable *CCPI* represents a corporation's home country CCPI ranking in 2006 (Germanwatch 2006).

Pressure by civil society. Echoing Dawkins and Fraas (2011) I use the Google News Archive to measure a corporation's media exposure to the issue of climate change. The archive collects and summarizes news stories from worldwide sources, such as newspapers, news agencies and aggregators. For each corporation in the sample, I searched its home country-specific Google News Archive site for articles published between January 1990 and December 2002. I searched for the corporation's name alone and for the corporation's name and the phrases 'climate change' and 'global warming'. Phrases and names have been translated into the home country's official language(s) with help of native speakers.

The metric variable *SOC* represents the share of climate-change-specific articles in all articles on a corporation published in the Google News Archive between January 1990 and December 2002.

[3]Thus, there is a misfit between the year of observation (i.e. 2006) and the year of the analysis (i.e. 2003). However, this misfit is accepted in favour of the level of detail reached with this measure for legislative pressure when compared with other possible measures, such as for example Kyob Protocol ratification.

Pressure by investors. Institutional ownership has been suggested to promote voluntary corporate reporting (Bushee and Noe 2000). A positive relationship has been shown between the amount of shareholder resolutions targeted at a corporation and its competitors and CDP participation (Reid and Toffel 2009). Following Stanny and Ely (2008) as well as Reid and Toffel (2009) I use institutional ownership as a proxy for pressure by investors.

The metric variable *SHARE* represents the percentage of total shares in issue held by pension or endowment funds as well as investment banks or institutions. This data is gathered from the Datastream database.

Pressure by final consumers. Echoing Moon (2008), Brouhle and Ramirez-Harrington (2010), industry sectors are taken as a proxy for final consumer orientation. Final consumer oriented corporations produce goods and provide services that need no further processing before sale to the final consumer. The final consumer is thus highly relevant for these corporations.

The categorical variable *CON* takes a value of one if a corporation is operating in the industry sectors consumer goods or consumer services in 2010. It takes a value of zero in all other cases. This data is also gathered from the Datastream database.

5.4 Control Variables

In deciding on control variables, I follow similar research in the environmental management domain. As will be detailed below, I choose control variables in a comparable way.

Environmental sensitivity. It has been argued that corporations operating in environmentally sensitive industry sectors are more likely to disclose non-financial information (Brammer and Pavelin 2008; Cormier et al. 2005; Kim and Lyon 2011b). In reference to Cho and Patten (2007), industry sector is taken as a proxy for environmental sensitivity. The following industry sectors are considered environmentally sensitive: aluminium, commodity chemicals, consolidated electricity, exploration and production, general mining, gold mining, integrated oil and gas, iron and steel, multiutilities, pharmaceuticals, and specialty chemicals. The categorical variable *ESI* takes a value of one if a corporation is operating in one of the above-cited industry sectors and a value of zero in all other cases.

Size. Empirical evidence suggests that larger corporations are more likely to disclose non-financial information because they benefit from lower information costs and are under higher public scrutiny (Clarkson et al. 2008; Kim and Lyon 2011b). Echoing Brouhle and Ramirez-Harrington (2010), Dawkins and Fraas (2011), Moon (2008), the metric variable *lnEmp* represents the natural log of total employees.

Profitability. Following the argumentation of information cost theory, a more profitable corporation disposes of more financial and other resources to voluntarily publish and disseminate non-financial information (Brammer and Pavelin 2006). For example, Stanny and Ely (2008) reveal a positive link between profitability and CDP participation. Accordingly, the metric variable *ROE* represents the return on equity.

5.5 Empirical Model

OLS regression is not applicable as my dependent variable *participation* is a categorical variable. Instead, I applied a logistic regression model (Hair et al. 1998) in order to assess the influence of my explanatory variables on CDP participation patterns. An ordinal logistic regression model could not be used because the proportional odds assumption does not hold.

Logistic regression models predict the probability of a certain outcome in comparison to a reference group. Because of the logistic relationship, the estimated regression coefficients specify the direction of influence, but not the strength of the relationship. Therefore, I analyse the exponential of the estimated regression coefficients, the so-called odds ratio. Odds-ratios are interpreted as follows:

- For a value of one, the probability of the analysed event occurring is independent of the independent variables.
- For a value below one, the probability of the analysed event occurring is smaller than in the comparison group.
- For a value exceeding one, the probability of the analysed event occurring is larger than in the comparison group.

6 Results and Discussion

Tables 1 and 2 provide an overview of my sample regarding CDP participation patterns by home country and aggregated industry sector. It can be seen that more than half of the corporations (51.1 %) are early participants. The residual share is almost evenly divided between late participants (21.5 %) and undecided participants (27.4 %). This high share of early participants in my sample might be explained by the fact that I am looking at the biggest corporations worldwide. It is empirically verified that corporate size positively influences corporate participation in voluntary climate change initiatives (Clark and Crawford 2012; Dawkins and Fraas 2011; Lee 2012; Moon 2008; Reid and Toffel 2009; Stanny and Ely 2008; Welch et al. 2000) and voluntary GHG reporting (Berthelot and Robert 2011; Brouhle and Ramirez-Harrington 2010; Ciocirlan and Pettersson 2012; Cotter and Najah 2012; Freedman and Jaggi 2005; Prado-Lorenzo et al. 2009; Prado-Lorenzo and García-Sánchez 2010; Rankin et al. 2011; Stanny 2013). In the case of my sample, corporations within the Global 500 are exposed to higher public scrutiny due to their high visibility to civil society. Supposedly, these corporations are thus more open to new mechanisms of voluntary environmental reporting, such as the CDP. This bias towards larger corporations in my sample needs to be kept in mind when interpreting the results.

Table 1 shows that more than 80 % of the corporations are headquartered in the Triad regions, i.e. in the USA, Europe and Japan. Looking at CDP participation

Table 1 CDP participation patterns by home country

	Total		Early participants		Late participants		Undecided participants	
	No.	% of total	No.	% of country	No.	% of country	No.	% of country
Australia	5	1.9	4	80.0	0	0.0	1	20.0
Brazil	1	0.4	1	100	0	0.0	0	0.0
Canada	11	4.1	4	36.4	4	36.4	3	27.3
China	1	0.4	0	0.0	0	0.0	1	100
Europe	78	28.9	43	55.1	18	23.1	17	21.8
Belgium	*1*	*0.4*	*0*	*0.0*	*0*	*0.0*	*1*	*100*
Denmark	*1*	*0.4*	*1*	*100*	*0*	*0.0*	*0*	*0.0*
Finland	*1*	*0.4*	*0*	*0.0*	*0*	*0.0*	*1*	*100*
France	*15*	*5.6*	*7*	*46.7*	*5*	*33.3*	*3*	*20.0*
Germany	*15*	*5.6*	*8*	*53.3*	*1*	*6.7*	*6*	*40.0*
Italy	*3*	*1.1*	*1*	*33.3*	*2*	*66.7*	*0*	*0.0*
Netherlands	*3*	*1.1*	*3*	*100*	*0*	*0.0*	*0*	*0.0*
Norway	*1*	*0.4*	*1*	*100*	*0*	*0.0*	*0*	*0.0*
Spain	*7*	*2.6*	*3*	*42.9*	*2*	*28.6*	*2*	*28.6*
Sweden	*5*	*1.9*	*2*	*40.0*	*2*	*40.0*	*1*	*20.0*
UK	*26*	*9.6*	*17*	*65.4*	*6*	*23.1*	*3*	*11.5*
Hong Kong	7	2.6	2	28.6	4	57.1	1	14.3
India	1	0.4	0	0.0	0	0.0	1	100
Japan	29	10.7	17	58.6	4	13.8	8	27.6
Mexico	2	0.7	2	100	0	0.0	0	0.0
Russia	3	1.1	1	33.3	0	0.0	2	66.7
Singapore	2	0.7	1	50.0	0	0.0	1	50.0
South Korea	1	0.4	0	0.0	0	0.0	1	100
Switzerland	8	3.0	3	37.5	2	25.0	3	37.5
United States	121	44.8	60	49.6	26	21.5	35	28.9
Total	270	100	138	51.1	58	21.5	74	27.4

patterns, more early participants than average are headquartered in Australia, Brazil, Europe, Japan and Mexico. As the number of observations for Brazilian and Mexican corporations is below three, any interpretation of frequency distributions needs to be accompanied with extreme caution. Finally, more late participants than average have their headquarters in Canada, Europe, Hong Kong and Switzerland. It is interesting to note the intra-European differences. When looking at those countries with three or more observations, I find that more than average German and Dutch corporations are participating early. More than average French and Spanish corporations are participating late. Finally, UK corporations exceed the average for both participation patterns but fall below the average regarding undecided participation.

Table 2 CDP participation patterns by aggregated industry sector

	Total		Early participants		Late participants		Undecided participants	
	No.	% of total	No.	% of sector	No.	% of sector	No.	% of sector
Financials	68	25.2	33	48.5	17	25.0	18	26.5
Basic materials	16	5.9	11	68.8	0	0.0	5	31.3
Consumer goods	35	13.0	20	57.1	7	20.0	8	22.9
Consumer services	27	10.0	10	37.0	11	40.7	6	22.2
Healthcare	21	7.8	12	57.1	2	9.5	7	33.3
Industrials	29	10.7	13	44.8	8	27.6	8	27.6
Oil and gas	19	7.0	9	47.4	3	15.8	7	36.8
Technology	18	6.7	6	33.3	5	27.8	7	38.9
Telecommunications	19	7.0	10	52.6	4	21.0	5	26.3
Utilities	18	6.7	14	77.8	1	5.6	3	16.7
Total	270	100	138	51.1	58	21.5	74	27.4

Comparative institutional approaches may shed light on these regional participation patterns (Hall and Soskice 2001; Whitley 1999). Hall and Soskice (2001) argue that national economic systems are the most relevant determinant for the implementation of abstract management concepts into organizational practice. The authors distinguish between liberal, coordinated and ambiguous market economies. In the case of CDP participation, corporations headquartered in Germany, the Netherlands and Japan may have been driven to participate in the CDP as of its beginnings because of pressures in their surrounding coordinated market economies. In comparison, corporations headquartered in Canada, France and Spain may have been less driven to participate in the CDP because of their surrounding liberal and ambiguous market economies and start participating as the CDP reaches a state of global institutionalization (Kolk et al. 2008). However, corporations headquartered in Switzerland and in the UK represent an exception to this comparative institutional interpretation. More Swiss corporations than average are late participants in spite of Switzerland being considered a coordinated market economy. UK corporations are embedded in a liberal market economy. Nonetheless, they exceed the average for both, early and late CDP participation. Whether and under what circumstances national economic systems can explain early versus late CDP participation could be an interesting topic for future research.

Table 2 shows that the majority of corporations are operating in the industrial, financial and consumer goods sectors. Regarding CDP participation patterns, more early participants than average are identified within the aggregated industry sectors basic materials, consumer goods, healthcare, telecommunications and utilities. More late participants than average are identified within the aggregated industry sectors financials, consumer services, industrials and technology.

A detailed look into the sub-sectors of these aggregated industry sectors may explain some of these sector-specific patterns. Of the aggregated industry sectors basic materials, healthcare and utilities most sub-sectors are environmentally sensitive. It is empirically verified that environmental sensitivity and participation in voluntary climate change initiatives (Brouhle and Ramirez-Harrington 2010) as well as in voluntary GHG reporting (Amran et al. 2011; 2005; Prado-Lorenzo et al. 2009; Rankin et al. 2011) are positively related. Therefore, I employ environmental sensitivity as a control variable in my regression analysis.

Finally, more than average late participants are operating in the consumer services industry. This seems to support my fourth Hypothesis that late participants were more likely under pressure to report GHG emissions by final consumers than other participants. However, I also find that more than average early corporations are operating in the consumer goods industry, which seems to oppose my fourth Hypothesis. I will analyse whether final consumer orientation has predictive power to explain late CDP participation in the regression analysis.

Table 3 provides descriptive statistics for my explanatory variables. I conducted Pearson's chi-squared tests for all categorical variables. These test the null hypothesis that the frequency distribution in the participation groups is statistically independent. I conducted Mood's median tests for the ordinal and metric variables. These test the null hypothesis that the medians in the participation groups are the same. In all three cases, the test statistic χ^2 has a chi-squared distribution with one degree of freedom under the null hypothesis.

The results show that the distribution of environmentally sensitive and non-environmentally sensitive corporations differs significantly between participation groups. Furthermore, regarding the CCPI ranking of a corporation's home country, I find that medians differ significantly between participation groups. Regarding my control variables, I find significantly differing medians for corporate size in both years and corporate profitability in 2010. It is also interesting to note that the median for institutional ownership is 5 % for late participants and zero for early and undecided participants. However, the test statistic is not significant. In the following, I apply regression analysis to investigate whether these explanatory variables have predictive power to explain CDP participation patterns.

6.1 Stakeholder Influences on Early CDP Participation in 2003

To test Hypotheses 1 and 2, that in 2003 new CDP participants were more likely under pressure to report GHG emissions by legislature (H1) and civil society (H2) than firms that will start participating later, I estimated the following model:

Table 3 Descriptive statistics for explanatory variables

	Total	Early participants	Late participants	Undecided participants	χ^{2a}
	% or median	% in group or median	% in group or median	% in group or median	
Industry sector is environmentally sensitive	24.1	64.6	7.7	27.7	10.635**
Industry sector is not environmentally sensitive	75.9	46.8	25.9	27.3	
Industry sector is final consumer oriented	23	51.6	24.2	24.2	0.583
Industry sector is not final consumer oriented	77	51.0	20.7	28.4	
Home country's CCPI ranking in 2006	46	34	52	52	41.927***
Share of institutional investors in 2010	0.00	0.00	5.00	0.00	4.019
Share of climate change specific articles in 2010	0.0229	0.0000	0.0398	0.0257	3.957
Natural log of total employees in 2002	10.7673	11.0157	10.6328	10.4401	7.346**
Natural log of total employees in 2010	11.1679	11.3510	11.0311	10.9765	4.914*
Return on equity in 2002	14.00	14.67	13.36	13.43	0.629
Return on equity in 2010	11.94	10.86	12.30	13.67	4.077*

*$p < 0.1$; **$p < 0.005$; ***$p < 0.005$

[a]Pearson's χ^2 test for categorical variables. Mood's median test for ordinal and metric variables

$$\begin{aligned} Logit\ P(participation = 1) = {} & \beta_0 + \beta_1 CCPI_{2006} + \beta_2 SOC_{2002} \\ & + \beta_3 ESI_{2002} + \beta_4 lnEmp_{2002} + \beta_5 ROE_{2002} \end{aligned}$$

Regarding the predictive ability of my logistic regression model and its goodness of fit, I analyse the likelihood ratio (LR) test statistic and Nagelkerke's R^2. The LR test statistic equals (−2) times the log-likelihood of the model including only the intercept minus (−2) times the log-likelihood of the model including all explanatory variables. It tests the null hypothesis that the explanatory variables are statistically independent of the dependent variable. Under the null hypothesis, the test statistic has a chi-squared distribution with the amount of explanatory variables representing the degrees of freedom. For the above-cited model, the LR test statistic equals 78.20 with ten degrees of freedom. Thus, the explanatory variables have a highly significant effect on CDP participation patterns. Values for Nagelkerke's R^2 range between zero and less than 1. The predictive power of a logistic model increases with increasing values for Nagelkerke's R^2. It has to be noted that values for R^2 in logistic regression are not comparable to OLS regression and need to be interpreted with caution. The above-cited model reaches a value of 0.290 which represents a fair fit.

Table 4 provides the estimated odds ratios and standard errors for the group of late and undecided participants compared to the group of early participants. I find that regarding the group of late and undecided participants, my variable for pressure by legislature is significant on a level of $p < 0.005$ and the related odds ratios are above one. Specifically, the value of 1.090 (1.029) indicates that a lower rating in the CCPI (i.e. an increase of the CCPI ranking) makes a corporation 9 % (3 %) more likely to belong to the group of late (mixed) participants than to the group of early participants, given that all other variables are held constant. In other words, with a rising CCPI ranking corporations are more likely to belong to the group of early participants than to the group of late or undecided participants in 2003. These results lend strong support to my first Hypothesis.

Furthermore, I find that regarding undecided participants, my variable for pressure by civil society is significant on a level of $p < 0.1$ and the related odds ratio is below one. In detail, the odds ratio of 0.613 indicates that given an increase in climate-change-specific articles by one unit, the probability for a corporation of being an undecided participant is expected to decrease by 40 %, given that the other variables are held constant. In other words, with a rising share of climate-change-specific articles corporations are more likely to belong to the group of early participants than to the group of undecided participants in 2003. I find no such relationship for the group of late participants. Therefore, my second Hypothesis is only supported when comparing the group of early relative to the group of undecided participants.

It is interesting to note that I find a significant influence of industry sector when comparing the group of late to the group of early participants with an odds ratio

Table 4 Results of the multinominal logistic regression analysis

		Standard error	Significance	Odds ratio
Undecided participation	Constant	1.011	0.828	–
	SOC	0.290	0.092*	0.613
	CCPI	0.008	0.001***	1.029
	ESI = 1	0.375	0.980	1.009
	$\ln Emp_{2002}$	0.087	0.196	0.893
	ROE_{2002}	0.006	0.483	0.996
Late participation	Constant	1.317	0.027**	–
	SOC	0.261	0.802	0.937
	CCPI	0.017	0.000***	1.090
	ESI = 1	0.609	0.007**	0.194
	$\ln Emp_{2002}$	0.101	0.222	0.884
	ROE_{2002}	0.001	0.158	1.002

The reference group is early participation. Explanatory variables are stated by row
n = 270; Nagelkerke's R^2: 0.290; LR: 78.20
$*p < 0.1$; $**p < 0.05$; $***p < 0.005$

below one ($p < 0.05$). Specifically, the odds ratio of 0.194 indicates that corporations operating in environmentally sensitive industries are 80 % less likely to belong to the group of late participants than to the group of early participants. In other words, operating in an environmentally sensitive industry largely increases the probability of a corporation to belong to the group of early participants in 2003.

6.2 Stakeholder Influences on Late CDP Participation in 2011

In the descriptive analysis I identified differences between corporations operating in the consumer goods and in the consumer services industry. Therefore, I decided to differentiate the explanatory variable *CON* into the additional variables $CON_{consumer\ goods}$ and $CON_{consumer\ services}$. The former focusses on corporations operating in the consumer goods industry while the latter regards those in the consumer services industry. To test Hypothesis 3 and 4, that in 2011 new CDP participants were more likely under pressure to report GHG emissions by investors and final consumers than firms that have started participating earlier, I thus estimated the following models:

$$\begin{aligned} (1)\quad & Logit\,P(\text{participation} = 2) = ß_0 + ß_1 SHARE_{2010} + ß_2 CON_{2010} + ß_3 ESI_{2010} \\ & \qquad + ß_4 lnEmp_{2010} + ß_5 ROE_{2010} \end{aligned}$$

$$\begin{aligned} (2)\quad & Logit\,P(\text{participation} = 2) = ß_0 + ß_1 SHARE_{2010} + ß_2 CON_{consumer\,goods,2010} \\ & \qquad + ß_3 ESI_{2010} + ß_4 lnEmp_{2010} + ß_5 ROE_{2010} \end{aligned}$$

$$\begin{aligned} (3)\quad & Logit\,P(\text{participation} = 2) = ß_0 + ß_1 SHARE_{2010} + ß_2 CON_{consumer\,services,\,2010} \\ & \qquad + ß_3 ESI_{2010} + ß_4 lnEmp_{2010} + ß_5 ROE_{2010} \end{aligned}$$

Regarding the predictive ability of the three models and their goodness of fit, I find that the LR test statistic is highly significant for all models. The highest value is reached in model 3 (37.97). Nagelkerke's R^2 reaches values of 0.140 (model 1), 0.139 (model 2) and 0.152 (model 3). Model 3 should therefore be preferred over the former models.

Table 5 provides the predicted odds ratios and standard errors for the group of early and undecided participants compared to the group of late participants. I find that regarding the group of early and undecided participants, institutional ownership is significant on a level of $p < 0.1$ in all three models. In all cases, the related odds ratios are below one. Specifically, the odds ratio of 0.939 in model 3 indicates that increases in shareholder ownership make a corporation about 6 % less likely to belong to the group of early participants, given that the other variables are held constant. In other words, with a rising share of institutional ownership corporations are a little more likely to belong to the group of late participants than to the group of early participants in 2011. The same is true for the group of undecided participants. This lends support to my third Hypothesis.

Table 5 Results of the multinominal logistic regression analysis

		Standard error			Significance			Odds ratio		
		Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Undecided participation	Constant	1.805	1.830	1.833	0.326	0.281	0.366			
	$CON_{industry} = 1$[a]	0.445	0.592	0.564	0.277	0.802	0.132	0.617	1.160	0.428
	SHARE	0.029	0.029	0.029	0.052*	0.067*	0.060*	0.945	0.948	0.947
	ESI = 1	0.574	0.565	0.567	0.103	0.057*	0.093*	2.550	2.930	2.595
	LnEmp_2010	0.164	0.162	0.163	0.420	0.327	0.462	0.876	0.853	0.887
	ROE_2010	0.010	0.009	0.009	0.348	0.500*	0.343	1.009	1.006	1.009
Early participation	Constant	1.809	1.804	1.809	0.132	0.155	0.104			
	$CON_{industry} = 1$*	0.393	0.522	0.501	0.363	0.384	0.040**	0.700	1.575	0.357
	SHARE	0.028	0.028	0.028	0.019**	0.028**	0.022**	0.937	0.941	0.939
	ESI = 1	0.541	0.532	0.535	0.002***	0.001***	0.002***	5.228	6.124	5.078
	LnEmp_2010	0.159	0.157	0.158	0.050*	0.073*	0.035**	1.364	1.326	1.396
	ROE_2010	0.010	0.009	0.009	0.245	0.361	0.230	1.012	1.008	1.011

The reference group is late participation. Explanatory variables are stated by row
n = 248; Nagelkerke's R^2: 0.140; LR: 34.77 (model 1)
n = 248; Nagelkerke's R^2: 0.139; LR: 34.42 (model 2)
n = 248; Nagelkerke's R^2: 0.152; LR: 37.97 (model 3)
*$p < 0.1$; **$p < 0.05$; ***$p < 0.005$
[a]Industry is represented by the sectors consumer goods & services (model 1), consumer goods (model 2) and consumer services (model 3)

Furthermore, I find that final consumer orientation is significant on a level of $p < 0.05$ for the group of early relative to the group of late participants in model 3. The related odds ratio is 0.357. Accordingly, the probability for corporations in the consumer services industry to belong to the group of early participants is 65 % less likely compared to the group of late participants. In other words, corporations in the consumer services industry are less likely than other corporations to belong to the group of early participants in 2011. Therefore, my fourth Hypothesis only finds support for consumer *service* orientation and when comparing the group of early relative to the group of late participants.

In line with my findings for the year 2003, I find a significant influence of environmental sensitivity when comparing the group of early to the group of late participants in all three models ($p < 0.005$). The related odds ratios are above one. In detail, the odds ratio of 6.124 in model 2 indicates that corporations operating in environmentally sensitive industries are more than six times more likely to belong to the group of early than to the group of late participants in 2011.

7 Conclusions

Three CDP participation patterns (early, late and undecided participation) are examined for the Global 500 at two distinct points in time (2003 and 2011). More than half of these corporations are categorized as early participants. In 2003, corporations under regulatory pressure are more likely to belong to the group of early CDP participants. In 2011, corporations under pressure by investors are more likely to belong to the group of late participants.

The evolution of managerial motivations and objectives for adopting environmental management practices has been empirically researched by Hoffman (1999), Bansal (2005). Supporting my findings, both studies reveal that pressures by legislature and civil society dominate managerial decision making at the start of new environmental practices.

My analysis of the timing of CDP participation supports strong social models of innovation diffusion research as it shows that legitimacy reasons play a strong role for CDP participation (cf. Stanny 2013). This ties in with the critique of Hesse (2006), Kolk et al. (2008) who doubt the value of the information reported to the CDP for non-managerial stakeholders, especially regarding investment decisions. Supporting this critique, the results of my study show that corporate engagement in voluntary GHG reporting is linked to different managerial motivations and objectives depending on the timing of participation. In 2003, by participating in the CDP right from its start, corporations satisfy the claims of legislature and civil society. In 2011, by participating in the CDP once the initiative is a globally institutionalized practice, corporations satisfy the claims of investors and final consumers. Nonetheless, my insights indicate that legislature, civil society, investors and final consumers are assessed as salient stakeholders regarding the issue of voluntary GHG reporting. Therefore, despite the ongoing debate about the usefulness of climate change regulation for corporate performances, my findings demonstrate that stringent climate change policies enhance voluntary GHG reporting.

My findings contribute to stakeholder theory and have important implications for policy making. Firstly, as regards the contribution to stakeholder theory, current empirical studies of voluntary GHG reporting focus on regulatory and financial stakeholders, such as lenders and investors. Other measures for non-financial stakeholders, such as civil society and final consumers, are mostly excluded from empirical research (for an exception see Sprengel and Busch 2011). This analysis therefore contributes to stakeholder theory by expanding the scope of existent measures.

Secondly, according to my results, the design of policies aimed at enhancing voluntary GHG reporting should account for different managerial motivations and objectives depending on the timing of participation. I suggest that in the beginning of such programs, policy makers should focus on instruments of communication and dialogue with regulators and the media, such as periodic reports, press conferences and round tables. Once the program reaches maturity, it should be complemented with instruments that address primary stakeholder claims, such as labels or benchmarking.

For long, voluntary environmental reporting was based on the mechanisms known from mandatory financial reporting and driven by initiatives that are utilizing these (Higgott et al. 2000). Both reporting types have in most cases been kept separately. Since 2009 however, a global coalition of policy makers, investors, corporations and especially accounting firms, standard setters, as well as non-governmental organisations, the International Integrated Reporting Council (IIRC), is engaged in mainstreaming the integrated reporting of financial and non-financial information. In addition, European policymakers are preparing binding rules for the reporting of non-financial information (Council of the European Union 2014; European Commission 2011). Against this background, the practical relevance of my findings for corporate decision makers becomes evident: the integrated reporting of non-financial information is currently in a situation where a rising number of corporations adopt this practice (Abeysekera 2013; Mustata et al. 2012; Singleton-Green 2010), supposedly to conform to the pressures of legislature and civil society. Already, claims of investors are expressed through the actions of the IIRC. It seems thus advisable for corporate decision makers to closely follow their stakeholders' claims regarding integrated reporting and to keep informed about this issue. Thus, professional managers will firstly be in a position to show action on integrated reporting in time and secondly they are prepared for a situation where integrated reporting is a globally institutionalized practice.

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Carbon Emissions and Corporate Financial Performance: A Systematic Literature Review and Options for Methodological Enhancements

Stefan Lewandowski

Abstract This paper systematically reviews the existing empirical literature on the linkage between carbon emissions and corporate financial performance (CFP). The results show that superior corporate environmental performance (CEP) pays off when market measures, such as Tobin's *q*, are linked to a firm's level of carbon emissions. However, modeling the relationship between carbon emissions and CFP is a complex task. This complexity is illustrated by methodological differences between the studies included in the review which may systematically influence the results. Therefore, a set of options for methodological enhancements is suggested which may guide further inquiries into the relationship between carbon emissions and CFP.

1 Introduction

Measuring corporate environmental performance (CEP) based on pollution indicators involves knowledge from various disciplines like chemistry, economics and engineering sciences. Therefore, management scholars attempting to further close the knowledge gap regarding the relationship between CEP and corporate financial performance (CFP) have to "transcend disciplinary boundaries" (Hirsch Hadorn et al. 2006: 124). This holds especially true if trying to quantify financial implications of pollution prevention with the help of statistical data as well as mathematical modelling techniques.

In recent years, an increasing body of empirical research has used self-reported carbon emission data for inquiries into the 'CEP-CFP nexus' (Günther et al. 2011).

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More specifically, a firm's level of carbon emissions is used as proxy for CEP in regressions on different accounting and market measures. Thereby, the studies aim at identifying a systematic relation between CEP and CFP. The results can then be used to derive conclusions about the potential impact of emission abatement on firms' financial bottom lines. Here, empirical management research can support corporate decision making regarding potential returns from investments in renewable energies and low-carbon technologies.

This paper systematically reviews the existing empirical literature on the relationship between self-reported carbon emissions and CFP. The literature review aims at synthesizing results across studies and at reaching conclusions regarding a possible 'business case for corporate sustainability' (Salzmann et al. 2005). The results indicate that superior CEP actually pays off when market measures, such as Tobin's *q*, are used in regressions on carbon emissions. However, recognizing the complexity accompanying the CEP-CFP nexus while building on the concept of transdisciplinarity in sustainability research (Hirsch Hadorn et al. 2006), this paper subsequently points to methodological differences between the reviewed studies. These differences may systematically influence the results. Therefore, a set of options for methodological enhancements is suggested which incorporates recent research findings and discussions from carbon accounting research. As a result, this paper supports further research focusing on the relationship between carbon emissions and CFP.

The remainder paper is organized as follows. Section 2 highlights empirical research on the CEP-CFP nexus as well as its background. It also deals with the relatively new phenomenon of carbon data available through mandatory or voluntary emission reporting schemes. Section 3 elaborates on the methodology employed in the literature review. The results are presented in Sect. 4. Subsequently, four possible methodological adjustments are presented (Sect. 5). Finally, conclusions are drawn and options for further research are suggested (Sect. 6).

2 Background

Studies investigating the relationship between CEP and CFP are mostly driven by theoretical arguments. Conventional wisdom assumes environmental protection to be a cost burden eroding a firm's competitiveness, whereas other scholars assume environmental pollution to be a waste of inherently scarce resources (Ambec and Lanoie 2008).

A tremendous body of empirical research inquires about a possible relation underlying the CEP-CFP nexus (frequently cited examples include the studies of Hart and Ahuja 1996, and Konar and Cohen 2001). After almost 40 years of empirical research (Günther et al. 2011), enhancements in CEP are perceived to positively influence CFP at least to a small degree (Orlitzky et al. 2003; Peloza 2009). However, as the evidence is mixed and underlying methodologies differ substantially (e.g. Horváthová 2010), the results are "far from conclusive enough to be considered satisfactory" (Günther et al. 2011: 279). Thus, the CEP-CFP nexus remains "one of the most puzzling phenomena pertaining to research on organizations and the natural environment" (Endrikat et al. 2014: 1).

Empirical management research on the CEP-CFP nexus is always confined to available CEP variables (Konar and Cohen 2001). However, not many of them are publicly accessible. Until recently, a vast part of early research relied on data from the Toxic Release Inventory (TRI) (for an overview, see, e.g., Molina-Azorín et al. 2009). The TRI database was established in the USA by the Environmental Protection Agency (EPA) and collects data about the release of toxic chemicals, such as aluminum oxide and phosphoric acid (for more details, see EPA 2014).

In recent years, CEP-CFP research has started to benefit from self-disclosed carbon emission data, which is increasingly available through several databases. In this paper, the term *carbon emission* refers to all six greenhouse gases covered by the Kyoto Protocol (for more details, see United Nations Framework Convention on Climate Change (UNFCCC) 2014). This kind of CEP data is collected through voluntary or mandatory reporting schemes such as the European Union Emission-Trading System (EU ETS) and the Carbon Disclosure Project (CDP).

From a theoretical point of view, constructing CEP variables based on carbon emissions is justified by increasing concerns among different stakeholders. The latter perceive the dependency on carbon-based materials and energy sources as increasingly constraining the competitiveness of firms (Busch and Hoffmann 2007). Especially, relatively high carbon emission levels are associated with mainly using fossil fuels. But fossil fuels are increasingly scarce and, therefore, are likely to experience massive price volatilities in the future (Busch and Hoffmann 2007). Moreover, businesses with high levels of carbon emissions are vulnerable to restrictive regulatory environments, which are implemented to combat global warming internationally. Accordingly, carbon emissions constitute an 'off-balance sheet liability' (Griffin et al. 2012), posing serious financial risks to businesses and financial investors.

3 Methodology

The literature review aims at synthesizing the results of empirical studies which rely on self-reported carbon emission data. Specifically, the review includes studies that provide quantitative estimates of the effect of (self-reported) firm level carbon emissions on CFP. It must be noted that this review does not intend to review the CEP-CFP literature in general.

Aiming for a high degree of comprehensiveness, the literature review followed a complementary multi-step methodology. In a first step, ProQuest's search engine ABI INFORM Complete was used to identify relevant articles published in 'Scholarly Journals' and work in progress presented in 'Working Papers'.

According to ProQuest, ABI INFORM Complete has become "the world's most comprehensive and diverse business database" providing "more of the information needed by business researchers than any other single source available" (ProQuest 2014). Two search strings were used, combining the terms 'carbon emissions' (or 'CO_2 emissions' or 'greenhouse gas emissions') *and* 'financial performance' (or 'corporate performance' or 'firm performance'). These search strings were than identified in the titles or abstracts of the literature within ABI INFORM Complete. This search led to a list with 140 documents. From this list, the author considered a total of 14 journal articles and two working papers relevant.

After having identified these 16 documents, the reference lists of the selected studies were screened manually. The aim was to identify studies with a similar methodological framework, but a terminology not considered by the search strings. This step added five journal articles and two working papers to the list of relevant studies. In addition, two journal articles and four working papers were added. These did not appear in ABI INFORM Complete nor in the references mentioned above. However, they were presented at conferences or known from other sources. In the end, a total of 21 journal articles and eight working papers were identified to be relevant for the literature review.

In a third step, studies not meeting a set of criteria were excluded. As already mentioned above, a study was required to estimate the effect of (self-reported) firm level carbon emissions on CFP. The study of Boiral et al. (2012) was excluded because they operationalize a firm's carbon performance based on a five-step rating scale rather than on the level of self-reported carbon emissions. Similarly, the studies of Chapple et al. (2013) as well as García-Sánchez and Prado-Lorenzo (2012) were excluded because they transform carbon emission levels into binary dummy variables. The study of Lee (2012) was excluded because the author employs cluster analysis. For similar reasons, the study of Kuo et al. (2010) was excluded because they apply correlational analysis instead of an econometric approach. The study of Sariannidis et al. (2013) was excluded because they estimate the effect of *global* carbon emissions on CFP. Finally, the working paper of Saka and Oshika (2010) was excluded and instead the recently published journal article was used (Saka and Oshika 2014).

4 Results

Based on the above described methodology, a total of 22 studies was considered relevant for this literature review. These 22 studies are separated into 15 journal articles and seven working papers (including papers presented at conferences). The series of studies was published between 2009 and 2014. Table 1 summarizes the studies included in the literature review. It also contains information regarding applied data sources, performance variables, and sample sizes, *inter alia*.

Table 1 Summary of empirical studies about carbon emissions and CFP

Author(s) (Year)	Emission data source	Sample	Carbon performance variable(s)	Scopecoverage	Financial performance variable (s)	Evidence of the business case for carbon mitigation
Pogutz and Russo (2009)	Company sustainability and CSR reports	177 firms (worldwide) from the *Fortune 500*, for the period 2002–2005	*GHG emission ratio* (measured as the ratio *between* firm total emissions divided by sales *and* industry total emissions divided by sales)	Unspecified	ROA, ROS, ROE, Tobin's *q*	Increases all variables
Brzobohatý and Janský (2010)	EU ETS data obtained from the Czech Ministry of Environment	125 Czech firms, for the period 2004–2006	Carbon *emission intensity* (measured as the ratio between total emissions and revenues)	1	Revenue, profit, costs	Increases revenue and costs
Delmas and Nairn-Birch (2010)	Trucost	1100 US firms, for the period 2004–2008	Total CO_2e emissions	1, 2, 3	ROA, Tobin's *q*	No clear evidence (increases Tobin's *q* but decreases ROA)
Tatsuo (2010)	Japanese Ministry of Environment, company environmental reports	129 Japanese manufacturing firms, for the year 2006	*Eco-efficiency* (measured as the ratio between sales and total emissions)	Unspecified	ROA	Increases ROA (for the chemical industry)

(continued)

Table 1 (continued)

Author(s) (Year)	Emission data source	Sample	Carbon performance variable(s)	Scopecoverage	Financial performance variable (s)	Evidence of the business case for carbon mitigation
Busch and Hoffmann (2011)	Own survey, data is obtained from Sustainable Asset Management (SAM)	174 firms (worldwide), for the year 2007	*Carbon intensity* (measured as the rescaled ratio between total emissions and sales)	1, 2	ROA, ROE, Tobin's q	Increases Tobin's q
Iwata and Okada (2011)	Toyo Keizai Corporate Social Responsibility Database	268 Japanese manufacturing firms, for the period 2004–2008	*GHG emission intensity* (measured as the ratio between total GHG emissions and operating revenue)	Unspecified	ROE, ROA, return on investment (ROI), return on invested capital (ROIC), ROS, Tobin's q	Increases ROA, ROI, ROIC, and Tobin's q (i.e., $q - 1$)
Alvarez (2012)	Company sustainability and CSR reports (websites)	89 firms (worldwide), for the period 2007–2010	Variation of total carbon emissions between two years	Unspecified	ROA, ROE	Increases ROA
Chen and Gao (2012)	eGRID	44 US firms, for the periods 2002–2003 and 2006–2008	*Carbon dioxide emission rate* (measured as the ratio between total carbon emissions and electricity generation in MWh)	1	Cost of equity, bond yield-to-maturity spread	Decreases both variables
Clarkson et al. (2012)	EU ETS data (own calculation), rely on CDP for further analysis	211 European firms, for the period 2006–2009	Total carbon emissions (measured as allocation shortfalls)	1	Stock price	Increases stock price

(continued)

Table 1 (continued)

Author(s) (Year)	Emission data source	Sample	Carbon performance variable(s)	Scopecoverage	Financial performance variable (s)	Evidence of the business case for carbon mitigation
Ennis et al. (2012)	CDP	50 UK firms from the FTSE 350, for the period 2006–2009	Total carbon emissions and carbon emission intensity (measured as the ratio between total emissions and revenue)	1, 2	Revenue, expected stock price return	No empirical evidence (estimations insignificant)
Griffin et al. (2012)	CDP	498 US firms from the S&P 500 and 264 Canadian firms from the TSE 200, for the period 2005–2009	Total carbon emissions	1, 2, 3	Stock price	Increases stock price
Hatakeda et al. (2012)	Japanese Ministry of Environment	1089 Japanese manufacturing firms, for the year 2007	GHG intensity (measured as the ratio between the product of total GHG emissions and emission trade price *and* total assets)	1	Profitability (after-tax cash flow)	No empirical evidence (decreases profitability)
Nishitani and Kokubu (2012)	Japanese Ministry of Environment, Japanese Standard Association	641 Japanese manufacturing firms, for the period 2006–2008	*Carbon dioxide productivity* (measured as the ratio between net sales and total emissions)	Unspecified	Tobin's *q*	Increases Tobin's *q*
Misani et al. (2012)	CDP	164 firms (worldwide), for the period 2006–2008	*Carbon intensity* (measured as the ratio between total CO_2 emissions and firm assets)	1	Tobin's *q*	Increases Tobin's *q*
				Unspecified		

(continued)

Table 1 (continued)

Author(s) (Year)	Emission data source	Sample	Carbon performance variable(s)	Scopecoverage	Financial performance variable (s)	Evidence of the business case for carbon mitigation
Fujii et al. (2013)	Japanese Ministry of Environment	Japanese manufacturing firms, for the period 2006–2008	Carbon efficiency (measured as the ratio between sales and CO_2 emissions)		ROA, ROS, capital turnover (CT)	Increases ROA and ROS
Lou and Tang (2013)	CDP	48 Australian firms, for the year 2010	Total CO_2 emissions	1, 2	Abnormal return	Increases abnormal returns (for scope 1 emissions)
Ngwakwe and Msweli (2013)	Company website (sustainability report)	1 firm (*3M company*), for the period 2002–2010	Total CO_2-equivalent emissions	1, 2	Dividend per share	Increases dividend per share
Nyirenda et al. (2013)	Sustainability reports	1 firm (anonymized mining company), for an unknown period	Emission reduction (measured as total CO_2-equivalent emissions)	Unspecified	ROE	No empirical evidence (estimations insignificant)
Wang et al. (2013)	CDP	69 Australian firms, for the year 2010	Total carbon emissions	1, 2	Tobin's *q*	No empirical evidence (decreases Tobin's *q*)
Matsumura et al. (2014)	CDP	256 from S&P 500, for the period 2006–2008	Total CO_2 emissions	Unspecified	Market value	Increases market value
				Unspecified	Market value	

(continued)

Table 1 (continued)

Author(s) (Year)	Emission data source	Sample	Carbon performance variable(s)	Scopecoverage	Financial performance variable (s)	Evidence of the business case for carbon mitigation
Saka and Oshika (2014)	Japanese Ministry of Environment	1094 Japanese manufacturing firms, for the period 2006–2008	Emission intensity (measured as the ratio between total emissions and sales)			Increases market value
Segura et al. (2014)	EU ETS	745 Spanish companies, for the period 2005–2010	Total carbon emissions (measured as allowance surpluses)	1	ROA	No empirical evidence (decreases ROA)

The names of the applied carbon performance variables were decided by the corresponding authors and are given in Table 1 without any terminological adjustment. While parts of the studies' analyses were often conducted with smaller sample sizes, Table 1 always indicates the largest sample size used in the corresponding study. In the bibliography at the end of this paper, each study included in the systematic review is marked with an asterisk in front of the reference itself.

The reviewed studies are very heterogeneous in their conceptualization of CFP variables. They either use accounting measures, market measures, or a combination thereof. The following sections highlight the results of the studies in terms of their respective conceptualization of CFP.

4.1 Carbon Emissions and Accounting Measures

Accounting measures reflect a company's economic success in the past. They can, thus, be considered as a backward-looking conceptualization of CFP (Delmas and Nairn-Birch 2010). The reviewed studies employ a broad range of accounting measures. The most commonly used are calculated as ratios, e.g. return on assets (ROA), return on sales (ROS), and return on equity (ROE). Accounting measures can be expected to relate with carbon emissions in all possible ways, depending on project-specific investment costs.

Comparatively low levels of carbon emissions (i.e., good CEP) can be *positively* associated with accounting measures. A positive relationship is in line with theoretical arguments presuming the existence of a business case for sustainability. Accordingly, companies can gain competitive advantages if their commitment to corporate sustainability is accompanied by either cost savings or revenue increases (Porter and Van der Linde 1995). Pogutz and Russo (2009), who investigated the relationship between CEP and CFP for a sample of multinational companies listed under the Fortune 500, support a positive relationship. Their findings suggest that low carbon emission levels are positively related to ROA, ROS and ROE. Tatsuo (2010), Iwata and Okada (2011), as well as Fujii et al. (2013) studied the relationship between CEP and CFP for samples consisting of Japanese manufacturing firms. Their findings support a positive relationship between comparatively low carbon emission levels and a broad range of accounting measures (e.g., ROA and ROS). However, such a relationship is not supported for each accounting measure or is—in some cases—not valid for all industries. The same holds for the study of Brzobohatý and Janský (2010). The authors analyzed the relationship between CEP and CFP for a sample of Czech firms regulated under the EU ETS. Alvarez (2012), in turn, gathered data for a sample of multinational firms in order to study the association between carbon emission mitigation (i.e., the variation of total emissions between two years) and ROA. The author's findings are similarly mixed.

Comparatively low carbon emission levels can also be *negatively* associated with accounting measures. A negative relationship is in line with conventional wisdom presuming pollution prevention to be a cost burden for shareholders (Hart and Ahuja 1996). This is the case when companies apply large mitigation projects which are accompanied by substantial increases in capital expenditures. A negative relationship between comparatively low carbon emission levels and ROA is supported by Delmas and Nairn-Birch (2010) who analyzed a sample of US firms, as well as by Segura et al. (2014) who analyzed a sample of Spanish companies. Hatakeda et al. (2012) also support a negative relationship between comparatively low carbon emission levels and accounting-based CFP measures for a sample of Japanese manufacturing firms. According to their results, low levels of carbon emissions are a precursor for lower profitability.

Last but not least, carbon emissions can be *unrelated* to the levels of accounting-based CFP measures. This is the case where companies pick ‘low hanging fruits’, i.e. reducing carbon emissions with negligible investment costs, or —in the best case—no costs at all, before moving to higher cost options (Sims et al. 2003). The absent relationship between a firm’s level of carbon emissions and accounting measures is supported by Busch and Hoffmann (2011). The authors analyzed an international sample of firms listed under the Dow Jones Global Index. According to their results, carbon emission levels have no significant impact on either ROA or ROE. Ennis et al. (2012) as well as Nyirenda et al. (2013), present similar results for a sample of UK firms from the FTSE 350, and a single-company sample consisting of a mining company, respectively.

4.2 Carbon Emissions and Market Measures

Market measures reflect investors’ evaluation of a firm’s financial performance in the future. Therefore, market measures can be considered as a forward-looking conceptualization of CFP (Delmas and Nairn-Birch 2010). The reviewed studies use a broad range of market measures. These include stock prices, abnormal returns, or dividends. The most frequently used measure is Tobin’s *q*. This indicator denominates the ratio between a firm’s market value and the replacement costs of its tangible asset base (Chung and Pruitt 1994). Accordingly, the measure reflects a firm’s *intangible* or *unrecorded* assets (e.g. the value of advertising, see Smith 2002). From a theoretical point of view, and as already established for accounting measures, market measures can be expected to be affected by carbon emission levels in all possible ways.

Comparatively low carbon emission levels can be *positively* associated with market measures. An increase in capital expenditures to enhance CEP reflects management efforts to address risks related to future changes in the business environment, such as regulatory changes or increasing costs due to emission trading

(Busch and Hoffmann 2011). Accordingly, investors may perceive comparatively low carbon emission levels as a competitive advantage securing long-term profitability. A positive relationship is supported by Nishitani and Kokubu (2012). The authors examined the relationship between CEP and Tobin's *q* for a sample of Japanese manufacturing firms. According to their findings, low carbon emission levels are positively related to market performance. Misani et al. (2012) obtained similar results for an international sample of firms. According to their results, CEP is positively related to Tobin's *q*. Further support for a positive relationship between CEP and Tobin's *q* is presented by Pogutz and Russo (2009), Busch and Hoffmann (2011), as well as Delmas and Nairn-Birch (2010). Saka and Oshika (2014), who studied a sample of Japanese manufacturing firms, also support a positive association between CEP and market-based CFP. According to their findings, low levels of carbon emissions are positively related to the market value. Matsumura et al. (2014) also support a positive relationship between CEP and the market value for a sample of US firms listed under the S&P 500. Further support for a positive relationship is presented by Clarkson et al. (2012) for a sample of European firms, as well as by Griffin et al. (2012) for a sample of North American firms. Both studies suggest a positive relationship between CEP and stock price. Ngwakwe and Msweli (2013), as well as Lou and Tang (2013), also support a positive relationship. While Ngwakwe and Msweli (2013) suggest that carbon emission reduction is positively related to dividend payments, the findings of Lou and Tang (2013) indicate that superior CEP is positively related to abnormal stock returns. Chen and Gao (2012) obtained similar results for a sample of US firms. According to their findings, enhanced carbon emission abatement is likely to decrease a firm's cost of equity and has negative impacts on bond yield-to maturity spreads.

Comparatively low carbon emission levels can also be *negatively* associated with market measures. This is the case when investors do not regard superior CEP as a form of intangible value. Analogous to accounting measures, investors may regard emission abatement efforts as a cost burden reducing a firm's profitability. Wang et al. (2013) support a negative relationship between CEP and market-based CFP. Their findings suggest that emission reductions decrease Tobin's *q* for a sample of Australian firms. The authors explain their diverging results referring to the "unique economic structure and development of Australia, particularly its dominant mining industry" (Wang et al. 2013: 1).

Last but not least, carbon emission levels can be *unrelated* to a firm's market performance. This can be observed when investors assume indifferent positions with respect to CEP. Ennis et al. (2012) found no empirical evidence of a relationship between carbon emissions and expected stock price returns for a sample of UK firms. So far, this is the only empirical study failing to determine an effect of carbon emission levels on market-based variables.

4.3 Summary of Findings

The results indicate that superior CEP pays off when market measures, such as Tobin's *q,* are used in regressions on carbon emissions. This not only shows that investors incorporate CEP in their investment behavior, but also shows that investors regard carbon emissions as intangible liability.

In contrast, there is no clear evidence that superior CEP pays off when accounting measures are used in regressions on carbon emission levels. Accordingly, the potential effect of carbon emission abatement on accounting measures such as ROA, ROE, or ROS is unclear. In fact, the results of the considered studies suggest impacts in every possible direction: positive, negative, or no effect. These mixed results indicate that each theoretical argument discussed above may be applicable and that the results are likely to be influenced by the choice of methodological frameworks and applied data.

The difference between the results obtained by market and accounting measures may be explained by a non-linear relationship between carbon emission abatement and CFP. While financial markets appear to generally reward enhancements in CEP, the effect of CEP on CFP may follow a non-linear relationship when accounting measures are used. While emission abatement appears to be generally profitable in the beginning, the effect might be turned around when CEP is enhanced beyond certain carbon emission levels and, subsequently, becomes negative (Tatsuo 2010).

5 Options for Methodological Enhancements

According to Hirsch Hadorn et al. (2006), transdisciplinary research "transcends disciplinary boundaries" and "goes beyond our normal conceptions of scientific disciplines" (Hirsch Hadorn et al. 2006: 120, 124). Transdisciplinary research also refers to academic research being driven by practitioner engagement (Brandt et al. 2013). Considering the underlying complexity of the relationship between a firm's level of carbon emissions and CFP measures, while also keeping in mind the rather mixed results presented in the literature review, the extent to which regression analysis is based on transdisciplinary research may have an influence on the reliability and validity of the results (for an overview of the concepts of reliability and validity, see Cooper and Schindler 2011).

In the following, a set of ideas for methodological enhancements is suggested. This set is intended to increase the degrees of validity and reliability in CEP-CFP research that relies on self-reported carbon emissions. The presented suggestions do not claim to be comprehensive. Rather, they are inspired by recent research in the field of carbon accounting, which basically deals with technical and methodological processes related to "tracking the current level of carbon emissions and developments over time" (Schaltegger and Csutora 2012: 4). Carbon accounting is best placed to provide valuable background information on the relevance of carbon emissions for different industries, the technical processes underlying carbon emission measurement, and carbon emission indicator development.

5.1 Creating Industry-Specific Emission Samples

Samples used in the reviewed studies differ substantially concerning *scope-coverage*. Following the Greenhouse Gas Protocol (GHG Protocol)—an accounting tool jointly developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD)—part of the studies account for carbon emissions in three tiered *scopes* (WBCSD and WRI 2004). Scope 1 covers emissions directly controlled and released by a company; scope 2 accounts for indirect emissions embodied in purchased energy; and scope 3 refers to other indirect upstream and downstream emissions along the value chain of a company (WBCSD and WRI 2004).

A first set of studies, e.g. Brzobohatý and Janský (2010) as well as Misani et al. (2012), uses scope 1 emissions as a CEP proxy. Misani et al. (2012) argue that only reductions of direct emissions require "radical technological change" which is in turn linked to structural capital expenditures and modifications in production systems (Misani et al. 2012: 22). Scope 2 emissions, in contrast, could be reduced without substantial investments "by a simple switch to electricity suppliers that use renewable sources or more efficient plants" (Misani et al. 2012: 13).

A second set of studies, e.g. Busch and Hoffmann (2011) as well as Lou and Tang (2013), operationalize CEP based on scope 1 and 2 emissions. Lou and Tang (2013) use scope 2 emissions even though they assume (and find) that indirect emissions are less likely to affect CFP than direct emissions. This results from indirect emissions being not subject to regulatory constrains—and, thereby, not representing a significant cost driver (Lou and Tang 2013).

A third set of studies operationalize CEP based on all three emission scopes. These studies highlight that direct emissions provide only limited insights about the full range of financial risks along the value chain (Hoffmann and Busch 2008; Sundarakani et al. 2010). In fact, for some sectors, "the largest sources of emissions may be buried further upstream than many companies may have previously perceived" (Huang et al. 2009a: 217). Delmas and Nairn-Birch (2010), for example, argue that the demand for transparency does not end with disclosing direct emissions. Rather, shareholders increasingly recognize the importance of emissions along the *whole* value chain. The authors emphasize that a company's costs related to the release of carbon emissions is not solely driven by direct emissions; instead, controlling and reducing indirect carbon emissions can also require considerable expenditures. The latter may substantially affect shareholder value generation (Delmas and Nairn-Birch 2010). Furthermore, emission intensive suppliers are likely to be affected by environmental regulation and, thus, bear a potential risk for cost increases if they cannot be adequately replaced with less carbon intense competitors (Delmas and Nairn-Birch 2010).

The scope-coverage applied in a study may significantly influence the obtained results. In this context, it is important to note that each industry's value creation relies on direct and indirect emissions differently. This is because carbon emissions are unevenly distributed along the value chain across firms and industries (Busch 2010). Huang et al. (2009a), for example, calculate the percentage share of scope 1 emissions for four different sectors in the USA. According to their calculation, direct emissions account for about 73 % of the total emissions in the crude oil and gas extraction sector, whereas they account only for around 10 % in the pharmaceutical sector, 4 % in data processing, and for no more than 2 % in the publishing sector (Huang et al. 2009a). Similarly, Matthews et al. (2008) show in their study that direct emissions account for 92 % of the total emissions in power generation, whereas only for 14 % on average across all industries. Tatsuo (2010) emphasizes that "direct consumption of energy and CO_2 emissions during production at car assembly plants are not very high" because "Japanese car manufacturers outsource about 70 % of their components" (Tatsuo 2010: 215). This is confirmed by Lee and Cheong (2011) who calculated the carbon footprint for the car manufacturing company Hyundai Motors Co. They estimated a total quantity of 135 t of direct emissions (scope 1) and 8486 t of indirect emissions (scope 2) (Lee and Cheong 2011). As a result, in car manufacturing, scope 1 emissions appear to reflect only a minor part of the total emissions. Indirect emissions are more relevant than direct emissions in other industries as well. Examples include companies involved in manufacturing computer devices or semiconductors as they consume substantial amounts of purchased energy (Huang et al. 2009b). However, for industries with large value chains, including scope 2 emissions can be similar insufficient. Huang et al. (2009b) state that most of the carbon emissions in the electronics manufacturing sector, e.g. the computer industry as well as circuit board and semiconductor manufacturing, are embodied in the supplies of purchased parts, components, chemicals, and other materials. Accordingly, scope 1 emissions may only adequately reflect CEP for samples constituting of energy utilities and other high-emitting industries. Brzobohatý and Janský (2010), for example, used data from Czech companies listed under the EU ETS. Since the emission trading system covers only high-emitting industries, scope 1 emissions can be considered as adequate approximation for CEP in this context. In contrast, for companies or industries emitting less direct than indirect emissions (such as car manufacturers), an operationalization of CEP based on scope 1 emissions may be threating the reliability of the results.

Considering the substantial differences in scope-coverage across the reviewed studies and recognizing that some studies may have used emission data constituting only a minor part of the overall pollution, some studies may only inadequately reflect CEP. Hence, the estimated causal effects may not adequately explain how changes in CEP actually affect changes in CFP. Therefore, future studies might want to consider whether their scope-coverage fits industry-specific distributions of carbon emissions along the value chain in order to make sure that they adequately reflect CEP.

5.2 Applying Forward-Looking Emission Indicators

Carbon emissions offer a wide range for measuring CEP and studies differ substantially in their methodological approaches to fulfilling this task. Basically, a firm's carbon performance can be measured in two different ways, either as (absolute) total emissions or as ratio.

A first set of studies operationalize CEP based on the absolute quantity of total emissions. This indicator, however, provides no information on how companies depend on carbon emissions for conducting their business activities. Furthermore, carbon emission levels can substantially vary over time, depending on the timely use of production capacities and the overall economic conditions. There may also be changes in emission levels due to special effects caused by mergers or process outsourcing (Hoffmann and Busch 2008). Country-specific regulations can also influence the level of carbon emissions. The reviewed studies try to address this problem through model specifications and the use of dummy variables. Thereby, *inter alia*, the studies control for a firm's leverage, industry, and company size. However, as control variables are often statistically insignificant, some studies may fail to capture economic variations across industries or countries.

A second set of studies relate a firm's absolute carbon emissions to a *business metric* or *functional unit* (e.g., sales or market value). Such measures account for changes in business activities during the same time period when carbon emission levels change (Hoffmann and Busch 2008). Depending on the form of standardization, the relation between total carbon emissions and a business metric can be used for measuring two different indicators:

First, relating the amount of total carbon emissions to a business metric leads to an indicator measuring a firm's *carbon intensity* (Hoffmann and Busch 2008). A firm's carbon intensity describes the extent to which its business activities depend on carbon emissions for a defined scope within a fiscal year (Hoffmann and Busch 2008). In other words, it indicates the quantity of carbon emissions a company releases in order to generate one monetary unit of revenue or profit. Carbon intensity measures are, for example, applied in the studies of Brzobohatý and Janský (2010), Busch and Hoffmann (2011), as well as Misani et al. (2012).

Second, relating a business metric to the quantity of emitted total carbon emissions leads to an indicator measuring a firm's *carbon efficiency*. This measurement concept is derived from the ecoefficiency literature (e.g., Schaltegger and Sturm 1990). A company's carbon efficiency reveals how much it earns for every ton of carbon emissions released into the atmosphere. Nishitani and Kokubu (2012), for example, apply such a ratio even though they refer to this measure as 'carbon dioxide productivity'.

A problem related to using all of the indicators described above is that they only reflect past emission levels. They contain no information on a firm's future emission levels or its strategy concerning carbon abatement activities. While this is a much debated issue in the accounting literature (Schaltegger and Figge 2000), the reviewed studies apply a combination of forward-looking market measures for an operationalization of CFP (e.g., Tobin's *q*) and a backward-looking measures for operationalizing CEP (e.g., total carbon emissions). This combination postulates that investors are expected to estimate a firm's future cash flows based on its status quo emissions rather than its ability to tackle related risks in the future. This sharply contrasts to the assumption that financial markets are likely to evaluate a firm's ability to take advantage of its asset base in order to realize optimization potentials for future emission mitigation instead of only taking its current emission levels into consideration (Hoffmann and Busch 2008).

Instead of using status quo carbon emissions for measuring backward-looking CEP, empirical studies might use risk indicators capturing future developments. Such variables, which can be called *forward-looking emission indicators*, are specified by Hoffmann and Busch (2008). These indicators may help to gain a better understanding of how financial investors are valuing financial risks related to current carbon emission levels.

5.3 Controlling for Methodological Diversity

Studies use emission data collected through various different reporting schemes. This *methodological diversity* may lead to differences in the reported quantity of total carbon emissions. These differences occur due to variations in applying these reporting schemes. Andrew and Cortese (2011), for example, conducted a study of 104 worldwide energy firms. Their study shows that although CDP directs reporting companies towards applying the GHG Protocol, carbon reporting methodologies vary substantially across their sample of companies. In some cases, the GHG Protocol is only used as a guideline for other reporting schemes which companies are actually following. Andrew and Cortese (2011) also show that companies often combine different reporting schemes and measurement frameworks in order to comply with both legislation requirements and voluntary reporting schemes like CDP. The problem related to the combination of various reporting schemes and the consequent lack of comparability is also stressed by Kolk et al. (2008). The authors stress that the application of diverging, industry or country-specific 'conversion factors' (e.g., provided by the UK Department for Environment, Food and Rural Affairs or the Intergovernmental Panel on Climate Change) constrains the comparability of carbon performances across companies (Kolk et al. 2008). This problem supports the view of Talbot and Boiral (2013), who state that "it appears impossible for a company to ensure that one ton of CO_2 equivalent in the metal-working sector represents one ton of CO_2 in the aluminum sector" (Talbot and Boiral 2013: 8).

Companies not just combine various reporting schemes but also apply more than one scheme simultaneously in order to account for regulatory differences across countries. In their article, Kolk et al. (2008) present the example of E.ON. The company reports its carbon emissions in Germany according to the Monitoring and Reporting Guidelines (MRG) of the EU ETS. In contrast, it reports its carbon emissions in the US according to the GHG Protocol on a voluntarily basis as it faces no other legislative requirements in this country (Kolk et al. 2008). Finally, Sullivan (2009) finds that companies inconsistently apply the definitions of the GHG Protocol, some include emissions from their vehicles in scope 1, whereas other companies list them under scope 3.

The reviewed studies obtained results based on samples comprising of companies which apply different methodological frameworks for carbon accounting. Considering the diversity of the applied reporting schemes, forthcoming studies may include dummy variables to capture differences in the application of reporting standards. As a result, studies could detect systematic differences in emission data related to a firm's choice of methodological framework.

5.4 Adjusting Emission Figures

Scholars involved in empirical analysis heavily rely on trustworthy data sources for collecting environmental indicators (Dragomir 2012). As Brown (1959) puts it: "However good the economic theory, the mathematical techniques, and the computational facilities, no useful econometric results can be obtained if the data are inadequate in quantity or quality" (Brown 1959: 26).

The reviewed studies exclusively use self-report emission data for an analysis of the CEP-CFP nexus. However, the quality of self-reported emission data has recently been questioned. As Andrew and Cortese (2011) observe, we are "a long way from producing quality carbon information" (Andrew and Cortese 2011: 137). This implies an inconsistency of quality levels between CFP measures and carbon emission data. Talbot and Boiral (2013), for example, conducted a case study of ten Canadian industrial firms from the aluminum, mine and pellet, petrochemical, and metallurgy industries in order to shed some light on carbon measurement practices. One interviewed manager admitted to have deliberately manipulated his company's reported emission figures for image reasons. This statement fuels concerns of 'green washing' (Talbot and Boiral 2013).

However, errors in carbon emission data might not only occur due to intended manipulation of emission figures. Rather, measurement errors may be caused by insufficient knowledge and limited understanding. Both factors restrict the capabilities of firms and audit companies to measure the actual quantity of released carbon emissions. In fact, there is little knowledge of how companies collect carbon emission data (Burritt et al. 2011; Gibassier and Schaltegger 2013), and recent research shows that companies still appear to be in a learning process (Engels 2009). Talbot and Boiral (2013) observe that limited scientific knowledge about the process of emission generation is likely to cause substantial discrepancies in estimating carbon emissions. More specifically, technical limitations may confine measurement accuracy to a maximum of 100,000 t and can be expected to generally vary by at least 10 % (Talbot and Boiral 2013). As some companies report emission reductions below 100,000 t (CDP 2014), this lack of accuracy constitutes a serious problem for the purpose of empirical analysis if this is based on self-reported carbon emission data.

For an assessment of studies' data reliability, emission factors could be used to evaluate the accuracy of self-reported emission figures. Koch and Bassen (2013), for example, estimated carbon adjusted cost of capital and equity values for a sample of European energy utilities. The authors estimated carbon emission levels based on generation capacities and emission factors of the fuel technologies. Another option would be to examine whether data differences exist between reporting leaders and reporting laggards in voluntary reporting schemes. This approach may deliver insights into the reporting behavior of firms and may provide a better understanding of whether companies use emission data from their rivals as a proxy for their own carbon performance. It would be possible to include dummy variables in future studies to capture the effect related to time differences in data reporting.

6 Conclusions and Further Research

The purpose of this paper was twofold. In a first step, it systematically reviewed the existing empirical literature on the relationship between self-reported carbon emissions and CFP. The aim was to synthesize the results in order to make a consequent statement regarding the existence of a business case for corporate sustainability (Salzmann et al. 2005). The results indicate that superior CEP pays off when market measures, such as Tobin's *q*, are used in regressions on carbon emission levels. This result does not only show that investors incorporate CEP in their investment behavior. It also indicates that investors regard carbon emissions as intangible liability. There is, however, no clear evidence on pay-offs caused by superior CEP when accounting measures are used in regressions on carbon emission levels. Consequently, the relationship between carbon emissions and accounting measures (such as ROA, ROE or ROS) remains unclear. In fact, the results of the considered studies suggest impacts in every possible direction: positive, negative, or no effect.

In a second step, a set of ideas for possible methodological adjustments was presented. These approaches may help to increase the degrees of reliability and validity. Specifically, the paper pointed to four options for methodological adjustments: (1) creating industry-specific emission samples, (2) applying forward-looking emission indicators, (3) controlling for methodological diversity in reporting schemes, and (4) indicator-based evaluations of self-reported emission figures.

To further base the analysis of the effect of carbon emission levels on CFP, it appears to be highly relevant to expand the interdisciplinary analysis to include research from the field of *Finance*. Hitherto, little is known about how investors technically account for carbon emissions in their investment decisions. Even where regressions detect a structural relation between carbon emissions and CFP variables, the results cannot be explained theoretically in the context of the basic concept of modern portfolio analysis, as introduced by Markowitz (1952). Specifically, it remains unclear how investors incorporate carbon emissions as a risk factor. The debate concerning 'double counting' is based in the same line of research. Carbon emissions may be doubly counted, or not counted at all, if a company sets its organizational accounting boundary within or outside the system of another company (Kolk et al. 2008). For investors, this complicates identifying the overall risk related to a specific portfolio (Busch 2011). In fact, incorporating a firm's full range of carbon emissions along the value chain would distort quantitative risk assessments if financial investors hold two companies pertaining to the same value chain in their portfolio.

Furthermore, it remains to be seen if and how investors perceive climate change and carbon emissions as a risk factor. One important step would be to conduct preliminary interviews with financial investors in order to gain a better understanding of how they incorporate carbon information in their investment decisions. This would be in line with the concept of transdisciplinarity stressing the importance of further engaging with practitioners. These interviews would also shed some light on the reliability of rather opinion-driven media reports as the latter observe that financial markets appear to not yet adequately appraise carbon emissions as a risk factor (e.g., Gore and Blood 2013).

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Organizational Climate Accounting—Financial Consequences of Climate Change Impacts and Climate Change Adaptation

Kristin Stechemesser, Anne Bergmann and Edeltraud Guenther

Abstract This study aims to investigate how climate change impacts and related climate change adaptation measures affect positions of traditional financial accounting, i.e. the balance sheet and the profit and loss account. We conduct a content analysis based on 57 in-depth expert interviews with CEOs of different industry sectors in one distinct region of Western Europe. Our analysis reveals that the balance sheet is affected mainly by climate change impacts on the following positions: intangible assets, tangible assets, inventories, receivables and other assets, cash-in-hand, prepaid expenses, and on equity/accruals/liabilities. The profit and loss account is influenced mostly by climate change impacts but also by related adaptive measures on the following positions: sales, own work capitalized, energy costs as part of material costs, material costs, personnel expenses, selling expenses, insurance costs, other operating income, other operating expenses, depreciations and amortization, disposal costs, interests, extraordinary income, and extraordinary expenses. Interestingly, the positions sales and energy costs, as part of material costs, can also be affected positively. To gain deeper insights, an investigation in other regions and industry sectors should be realized. Furthermore, based on our definition of organizational climate accounting and our classification into a three-stage approach, we suggest three areas for future research: first, to analyze the traditional financial accounting for the mitigation perspective; second, to investigate if organizations should react rather anticipatorily or reactively by using the Net-Effect; third, to analyze the environmental impacts of mitigation and adaptation measures by realizing a life cycle assessment. We contribute to accounting science by conducting the first comprehensive study on how climate change impacts and related climate change adaptation measures influence traditional financial accounting. Additionally, we propose a definition for organizational climate accounting.

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1 Introduction

Climate change mitigation but also the potential failure of climate change adaptation represent two of the most challenging global risks (World Economic Forum 2013) and are considered to have substantial effects on organizations as well as on global society as a whole (e.g. Busch and Hoffmann 2009). To deal with climate change effects, organizations can follow two different response strategies: mitigation and adaptation (Dlugolecki 2008). Mostly, prior studies investigated how organizations seek to reduce their greenhouse gas (GHG) emissions, i.e. mitigation, (Galbreath 2011), and thus have taken an inside-out perspective (Winn and Kirchgeorg 2005). However, considerably fewer studies analyzed issues of climate change from an outside-in perspective (Winn and Kirchgeorg 2005). These studies primarily investigate how climate change affects organizations and how they (could) adapt to the changing natural environment (e.g. Berkhout et al. 2006). Studies explicitly focusing on financial consequences of climate change impacts and related adaptation measures could not be identified. Therefore, we want to investigate how climate change impacts and related climate change adaptation measures affect positions of traditional financial accounting. To answer our research question, we analyzed 57 semi-structured interviews conducted with experts mainly in one distinct region of Western Europe.

We therefore contribute to climate change adaptation literature in two ways: first, our analysis represents the first systematic study of financial consequences of climate change impacts and related adaptation measures; second, we define the related term of climate accounting.

Our paper is organized as follows. First, we define climate accounting by extending the definition of carbon accounting through climate vulnerability accounting. Then, we review the existing literature concerning financial consequences of climate change impacts and climate change adaptation. After explaining the methodology, we present and discuss in Sect. 4 the results of the content analysis. In Sect. 5, we summarize our results, point out the limitations of the study, and present a future research agenda.

2 From Carbon Accounting to Climate Accounting

What do climate accounting or related terms such as climate change accounting, climatic accounting or accounting for climate (change) mean? The literature provides no explicit definition of these terms although the terms climate accounting (Hirschfeld et al. 2008; Searchinger et al. 2009), climate change accounting (Lovell and MacKenzie 2011; Milne and Grubnic 2011; Ngwakwe 2012; Pignatel and Brown 2010), and accounting for climate change (Andrew and Cortese 2011; Milne and Grubnic 2011) are used by several scientists. According to Hirschfeld et al. (2008), climate accounting can be understood as “Accounting for the impact on the climate of […] production processes" with the aim "to compare the effects on the climate of different […] production processes." (p. 11). Schaltegger and Csutora (2012) differentiate between carbon accounting and climate change accounting: carbon accounting considers only carbon emissions; climate change accounting takes further greenhouse gas (GHG) emissions into account by applying their global warming potential. Ngwakwe (2012) refers climate change accounting to emission accounting and GHG foot-printing, but also to carbon capture and storage, including sequestration calculations. Contrarily, Brown et al. (2009) describe accounting of climate change as comprising of "reviews of climate change reporting, stakeholder reactions to disclosures of climate change information, new systems of accounting designed to incorporate climate change performance, discussion about the role of accounting in promoting or undermining the climate change, environmental audit, discussion about general climate change conditions, climate change accounting policies, climate change coverage of product and process related information, climate change financial related data, sustainability, environmental aesthetics, development of theories to explain or inform climate change accounting practices, and discussion of methods and methodological issues associated with this research." (p. 6)

Stechemesser and Guenther (2012) suggest, without defining climate accounting, to extend the term carbon accounting to climate accounting whereby carbon accounting is understood interdisciplinarily as "the recognition, the non-monetary and monetary evaluation and the monitoring of greenhouse gas emissions on all levels of the value chain and the recognition, evaluation and monitoring of the effects of these emissions on the carbon cycle of ecosystems." (p. 35) At the organizational level, carbon accounting is understood by Stechemesser and Guenther (2012) as "the voluntary and/or mandatory recognition of direct and indirect GHG emissions, their evaluation in non-monetary and monetary terms as well as their auditing and reporting for internal purposes (carbon management accounting) and external purposes (voluntary and mandatory carbon financial accounting" (p. 33). Similar to Stechemesser and Guenther (2012), Ascui and Lovell (2012) and Burritt et al. (2011) differentiate between physical and monetary carbon accounting for internal or external purposes.

For internal purposes, organizations could develop carbon flow accounting (physical) or carbon cost accounting (monetary) and could integrate monetary and non-monetary information into strategic carbon management accounting (Ascui and Lovell 2012). The introduction of the emission trading systems (ETS) in the European Union resulted in costs arising due to allocated or purchased allowances (Bebbington and Larrinaga-González 2008).

For external purposes, the carbon footprint of products or organizations can be labeled and reported. Additionally, the ETS influences the balance sheet: European Union Allowances (EUAs) are considered as assets and the obligation to deliver allowances as liabilities (Bebbington and Larrinaga-González 2008). According to Bebbington and Larrinaga-González (2008) to maintain a 'true and fair view' of the organizational performance, non-financial reporting will be needed to inform about climate change impacts and adaptation to these impacts.

The organizational related definition of carbon accounting is partly consistent with explanations of Hirschfeld et al. (2008), Ngwakwe (2012), and Schaltegger and Csutora (2012) that focus only on a non-monetary evaluation of GHG emissions. But also parts of Brown et al. (2009), i.e. "climate change financial related data" (p. 9), are considered within the definition of Stechemesser and Guenther (2012).

Additionally, the above mentioned publications mostly do not consider the financial consequences of climate change impacts on organizations including, on the one hand, level effects, e.g. in average changing temperatures or precipitation amounts, and on the other hand, stability changes, e.g. extreme weather events (Stechemesser and Guenther 2012). One exception is presented by Bakhshi and Krajeski (2007), who explain for a fictional organization under the heading "Accounting for Climate Change" how climate change might affect an organization's balance sheet, especially its assets and liabilities. They are taking into account, on the one hand, effects arising from improving buildings to environmentally sustainable buildings to meet specific standards or from introducing new energy efficient product portfolio on profit growth in order to mitigate climate change effects. Another typical impact on the balance sheet arises from the EU ETS as described above. On the other hand, Bakhshi and Krajeski (2007) assume to pay higher insurance premiums and to realize asset write-downs resulting from hurricane damages. The first examples present the inside-out perspective (Winn and Kirchgeorg 2005), or how an organization affects the biophysical environment, i.e. climate change (Tashman 2011). The second examples describe the outside-in perspective (Winn and Kirchgeorg 2005), or how the biophysical environment influences organizations, which also reflects the organizational dependency of ecosystem services or their organizational vulnerability (Tashman 2011) (see Fig. 1).

From an organizational perspective, vulnerability can be understood as "the degree to which a business organization is susceptible to, or unable to cope with, adverse effects of climate change" (Bleda and Shackley 2008, p. 521). To reduce the dependence on resources, organizations can implement adaptation strategies (Tashman 2011). But according to Hoffmann et al. (2009), a higher vulnerability of an industry sector is not reflected in a higher level of adaptation. Hence, although the more vulnerable industry sectors might have more financial impacts from direct climate change effects, they might not be the ones with the highest financial expenses for climate change adaptation.

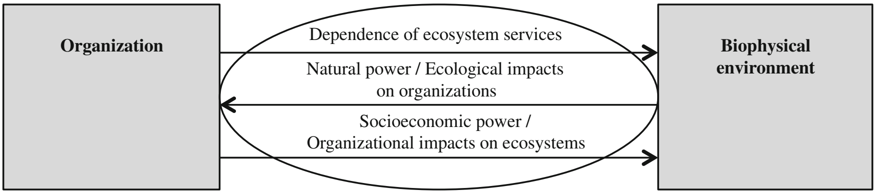
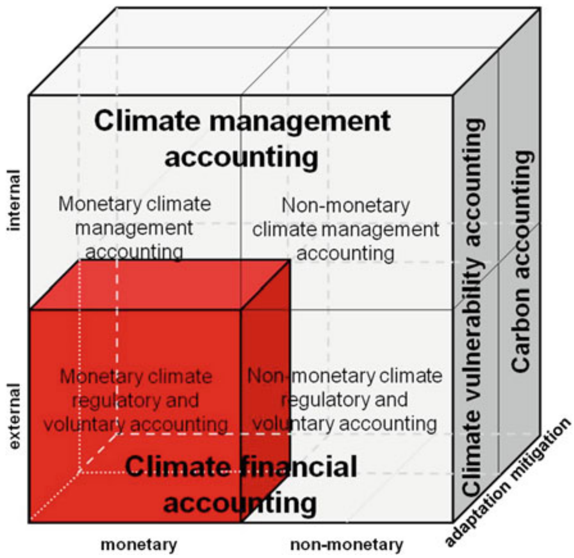


Fig. 1 Interdependence of organization and biophysical environment (*source* Tashman 2011)

To consider the outside-in-perspective, i.e. the accounting for climate vulnerability, we extend carbon accounting to climate accounting. We understand climate accounting as the recognition, the non-monetary and monetary valuation and monitoring of GHG emissions as well as climate change impacts and its response options on all levels of the value chain. Focusing on the organizational level, we suggest the following rather specific definition taking into account the definition of carbon accounting of Stechemesser and Guenther (2012) as well as the explanations above regarding carbon management accounting and carbon financial accounting: climate accounting at the organizational scale can be summarized as the voluntary and/or mandatory recognition of direct and indirect GHG emissions as well as the direct and indirect impacts of climate change and its response options, their evaluation in non-monetary and monetary terms, as well as their auditing and reporting for internal purposes (climate management accounting) and external purposes (voluntary and mandatory climate financial accounting). Based on our definition, the following cube can be deduced (see Fig. 2) that considers three perspectives: a monetary and a non-monetary perspective; an internal and an external perspective; and the two response options to climate change: mitigation and adaptation. Based on our definition, we can differentiate between climate vulnerability accounting and carbon accounting. In the following, we focus on the monetary values of climate vulnerability accounting (red box in Fig. 2) and, thus, on traditional cost accounting.

Fig. 2 Climate accounting at organizational level



3 Financial Consequences of Climate Change Impacts and Climate Change Adaptation

Although no scholars have investigated how climate change impacts and related climate change adaptation affect the balance sheet or the profit and loss account directly, literature provides some hints regarding the financial consequences. Therefore, we present the findings of a recent literature review on financial consequences of climate change impacts and climate change adaptation separated into the consequences for the balance sheet and the profit and loss account.

3.1 Financial Consequences on the Balance Sheet

Focusing on the balance sheet, impacts on *tangible assets* were observed such as damages to buildings and altered asset values (Busch 2011; Maynard 2008) and, thus, decreasing lower returns on investments (Maynard 2008). Considering insurance companies, *liabilities* increase as a result of higher damages (Botzen et al. 2010; Dlugolecki 2000; Dlugolecki and Keykhah 2002; Hawker 2007; Herweijer et al. 2009; Sato and Seki 2010) and, therefore, more *capital* is required (Hawker 2007; Maynard 2008). To conclude, prior studies detect the organizational balance sheet being affected on both sides, primarily (Maynard 2008). As already pointed out above, the fictional case of Bakhshi and Krajeski (2007) shows that climate change impacts can influence the position *Cash and cash equivalents* (cash as part of currents assets) by increasing insurance costs and the position *Property and equipment* (tangible assets) due to write-downs to the property account.

In the literature, several response options to climate change impacts can be identified which are mostly linked to costs and revenues. The costs include *investment costs* and, thus, a change in *tangible assets* (Becken 2005; Hoy et al. 2011), for example for snowmaking machines (Pickering and Buckley 2010), water distribution infrastructure (Subak 2000), or the laying of power cables in the ground (Linnenluecke et al. 2011). According to Dessai and Hulme (2007), the more robust an adaptation measure to climate change uncertainties, the more expensive the adaptation measure is.

Indications concerning positive impacts on the balance sheet could not be identified in the scientific literature.

3.2 Financial Consequences on the Profit and Loss Account

According to the literature, impacts from climate change influence organizational costs and revenues, especially by decreasing *sales* or *profit* (Botzen et al. 2010; Dlugolecki and Keykhah 2002; Maynard 2008; Mills 2003, 2009; Moen and

Fredman 2007; Pickering and Buckley 2010; Surugiu et al. 2010; Ward et al. 2008) or by resulting in losses (Bank and Wiesner 2011; Elsasser and Bürki 2002; Hoy et al. 2011). To compensate for losses in winter tourism, summer tourism could be developed (Hoy et al. 2011). According to Reidsma et al. (2010), a changing climate can result in profits or losses depending on the geographic region of the agricultural organization.

Looking at the profit and loss account, the following positions are influenced: *personnel expenditures* [for example due to lower productivity of employees or personnel shortages (Wedawatta et al. 2011)] and *material costs* [for example due to purchased resources (Busch 2011)], or (higher) *operational* (Busch 2011; Mills 2009) and *maintenance costs* (Busch 2011), including *service costs* (Busch 2011). Additionally, Busch (2011) mentions *insurance costs* that are part of *other operating expenses*, and Hawker (2007) discusses *capital costs*. In the specific case of water treatment costs, positive as well as negative developments can be observed. On the one hand, water treatment costs can decrease as a consequence of higher water quality (Thorne and Fenner 2008). On the other hand, decreasing water quality (Meuleman et al. 2007; Thorne and Fenner 2011) results in decreasing useful life of filters and increasing chemical input (Thorne and Fenner 2011).

Furthermore, implementing specific adaptation measures results in *operational costs* (Pearce et al. 2011) such as *energy and water costs* for snowmaking machines (Moen and Fredman 2007) or in *maintenance costs* (Becken 2005; Pearce et al. 2011). Additionally, a changing climate can require adapting the type of transportation, which can result in higher *transportation costs* (Pearce et al. 2011). Heavier precipitation could lead to water discharge, including sewage, into the river, which can cause *financial penalties*. Adaptation of insurance policies or withdrawal from the market could result in reputational damage and thus in decreasing *stock prices* (Maynard 2008). Contrarily, adapting to climate change impacts, for example, by providing new products and services, can result in higher *sales* (Herweijer et al. 2009).

4 Methodology

To realize our research objective, we applied a case study design (Dul and Hak 2008) because climate change, including extreme weather events, are being described as one of the most significant risks (World Economic Forum 2013). Thus, climate change can be classified as a present-day phenomenon which is a requirement for conducting case studies (Yin 2003). Moreover, Yin (2003) recommends conducting case study research when attempting to answer "how" questions. In addition, Eisenhardt (1989) suggests case studies in order to answer questions of causality and details.

4.1 Sampling Method

To select our cases, we combined different sampling strategies. First, we chose seven different industry sectors by using the "a priori determination". Therefore, we determined two criteria: climate sensitivity[1] and economic relevance.[2] According to our analysis, the energy and the water sectors as well as the transportation industry, as part of the tourism industry, can be classified as energy sensitive. Water sensitive industries are the food and tobacco industry, as part of the manufacturing industry, and the hospitality industry, as part of the tourism industry. Of high economic relevance is the construction industry, but also the mechanical engineering industry. To consider new emerging markets that are not part of current statistical systems, we also included companies from the high-tech industry.

In a second step, we defined the following criteria to choose companies: situated in a predefined geographic region in Germany, the head offices or their regional offices are located in that region, and more than ten employees. Overall, we identified more than 1000 companies (data provided by Chamber of Commerce, Dresden).

In a third step, we applied a typical case sampling method in order to select companies that are typical representatives of the industry sector, such as producers of meat/meat products or fruit and vegetables for the food and tobacco industry. Lastly, our sample includes 57 organizations of all sizes: thirteen organizations from the high-tech industry (H), twelve organizations from the tourism industry (T), nine organizations from the mechanical engineering industry (M), nine organizations from the water and sewage supply industry (W), six organizations from the food and tobacco industry (F), four organizations from the energy supply industry (E), and four organizations from the construction industry (C). All relevant data is provided in Table 1. In order to arrange an interview appointment, firstly a letter of invitation was sent to all corporations, and then all the companies were called by phone.

4.2 Data Collection

We conducted semi-structured German language face-to-face interviews[3] with experts (Meuser and Nagel 2009); this means the managing director of the company

[1]Climate sensitivity consists of water intensity and energy intensity. Water intensity: relation of water input to the gross value added of the industry sector. Energy intensity: relation of energy input to the gross value added of the industry sector.

[2]Regional gross added value compared to gross added value of Germany and regional number of people in employment compared to number of people in employment in Germany; calculated for every industry sector.

[3]Two interviews were conducted via phone.

Table 1 Case profiles

Organization	Industry	Organizational size[a]	Organization owner	Interviewee's position
H1	High-tech industry (H)	2	Yes	Managing director
H2		4	No	Managing director
H3		3	No	Head of Development
H4		3	Yes	Managing director
H5		3	No	Managing director (CTO)
H6		2	No	Authorized Signatory
H7		4	No	Environmental Manager, PR (2 persons)
H8		1	Yes	Managing director
H9		2	Yes	Managing director
H10		4	No	Head of Technology Controlling
H11		3	No	Director Research and Development
H12		2	Yes	Managing director
H13		3	No	Managing director
T1	Tourism industry (T)	2	Yes	Managing director
T2		2	Yes	Managing director
T3		2	No	Managing director
T4		1	Yes	Managing director
T5		2	No	Managing director
T6		2	Yes	Managing director
T7		3	No	Managing director
T8		2	Yes	Managing director
T9		3	Yes	Managing director
T10		3	No	Managing director
T11		3	Yes	Managing director
T12		3	No	Managing director
M1	Mechanical engineering industry (M)	3	Yes	Managing director
M2		3	No	Managing director
M3		3	No	Managing director
M4		3	Yes	Managing director
M5		2	Yes	Managing director
M6		3	Yes	Managing director
M7		2	Yes	Managing director
M8		3	Yes	Managing director
M9		3	Yes	Managing director

(continued)

Table 1 (continued)

Organization	Industry	Organizational size[a]	Organization owner	Interviewee's position
W1	Water and sewage supply industry (W)	4	No	Managing director
W2		4	No	Department manager
W3		3	No	Managing director
W4		3	No	Managing director
W5		2	No	Area manager
W6		3	No	Managing director
W7		2	No	Managing director
W8		2	No	Managing director
W9		2	No	Authorized signatory
F1	Food and tobacco industry (F)	3	No	Managing director
F2		3	Yes	Managing director
F3		3	No	Managing director
F4		3	No	Managing director
F5		4	No	Plant manager
F6		3	Yes	Managing director
E1	Energy supply industry (E)	2	No	Managing director
E2		2	No	Department manager
E3		4	No	Department manager
E4		4	No	Department manager
C1	Construction industry (C)	3	No	Authorized signatory
C2		2	Yes	Managing director
C3		4	No	Assistant to the management board
C4		4	No	Sales representative

[a]Classification according to the European Commission (2003) (number of employees): *1*—microenterprises; *2*—small enterprises, *3*—medium enterprises, *4*—large enterprises

or a person with a comparable position. In order to create new (additional) questions spontaneously and to avoid limited answers, we decided for a semi-structured interview guideline (Groenman 1992).

The questions comprise, on the one hand, questions concerning the profit and loss account and, on the other hand, questions regarding the balance sheet. We decided for these financial indicators because corporations (in Germany) are legally obligated to draw up an annual financial statement consisting of an annual balance sheet and a profit and loss account.[4] But also international accounting regulations such as the International Financial Reporting Standard (IFRS) refer to the

[4]See § 242 III HGB (Fleischer 2013). Abbreviation of German Commercial Code originates from German term Handelsgesetzbuch.

instruments of balance sheet and profit and loss statement as being recognized as the core of financial statements (Coenenberg et al. 2007).

Balance sheets summarize corporate assets and liabilities (§ 242 I HGB). Contrarily, profit and loss accounts compare expenses and income (§ 242 II HGB). Both instruments differ regarding temporal coverage: balance sheets represent all assets and liabilities on a specific date; profit and loss accounts comprise expenses and income over a determined time period (Döring and Buchholz 2009). Besides, profit and loss accounts include data that are important for success in terms of profit and loss and are relevant for external financial accounting.[5]

The questions about financial effects of climate change impacts and related adaptation were embedded in broader interviews about climate change impacts and related response options. To consider all items of the profit and loss account and the balance sheet, the interviewees received relevant templates. All interviews were recorded and professionally transcribed. Anonymity was guaranteed to respondents.

4.3 Data Analysis

We analyzed the transcripts by using a qualitative content analysis approach in order to make "replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use." (Krippendorff 2004, p. 18) To build categories, we combined a deductive and an inductive approach (Früh 2007; Krippendorff 2004) by using the profit and loss account and the balance sheet as main categories. For a more detailed analysis we differentiated on the sub-category level between financial consequences arising from climate change impacts and financial consequences resulting from the adaptation to these impacts. Additionally, we separated answers about experienced financial consequences currently or in the past from answers concerning expected financial consequences.

Beforehand, we explained the sub-coding in detail to differentiate sub-codings from each other and to assure a common understanding on sub-codings among the scientists. Moreover, we described coding rules such as the coding of whole sentences, but, if possible, every financial position separately, or that repetitions have to be coded again.

To assure a valid and reliable coding system and coding (Früh 2007), we conducted a pre-test with a few organizations. After that, we reviewed the categories critically and discussed them within the research group (Kvale 1995). We firstly investigated every interview independently, then we analyzed every sub-code separately. Finally, we discussed all codes within the research group (Kvale 1995). The coding is proceeded by using MAXQDA software.[6]

[5]For instance, Coenenberg's (2005) approach of analysis of annual financial statement (Coenenberg 2005).

[6]http://www.maxqda.com.

5 Results and Discussion

The following chapter presents the results of the performed content analysis. First, the results of the analysis of the balance sheet are provided, followed by the results of the analysis of the profit and loss account. Although the balance sheet and the profit and loss account are closely intertwined (Coenenberg et al. 2007), we only coded the primary impact mentioned by the interviewee.

5.1 Impacts on Balance Sheet

All results of our analysis for affected positions of the balance sheet are listed in Table 2. Our conducted content analysis identifies impacts of climate change on balance sheets for 63 % of interviewed organizations. Whereas these 36 companies report impact on *assets*, only two organizations (T6, W4) see an impact of climate change on *equity and liabilities*. As described in the methodology part, we distinguished between financial consequences either due to climate change impacts or by realized adaptation measures. There are 21 organizations reporting on climate change impacts on positions of balance sheet. Regarding the financial consequences of realized adaptation measures, we identified 25 organizations. Almost all realized adaptation measures pertain to the position of *tangible assets* (44 % of organizations relate to tangible assets). Since also 30 % of organizations see climate change impacts affecting these positions, in sum 60 % of interviewed organizations report tangible assets as the main position of the balance sheet being affected. Regarding *fixed assets in general*, there are just two organizations seeing an impact either by adaptation measures (T7) or by climate change impacts (E1). *Inventories* represent the second most affected position, which lags far behind affected tangible assets with only four impaired organizations. Whereas two of these organizations (H12, F2) report on climate change impacts, the other two (T6, T7) relate adaptive measures to changing position of inventories.

> Looking at it from this side, some issues exist. Inventories. When it gets too hot, such as silage, problems arise, of course. This effects everything somewhere. (F2, 86)

In the following, we further identified only a few other affected positions on corporate balance sheets. To start with, two organizations see overall negative concernment (M6, M9).

> The biggest dilemma, we said it at the beginning, was the flood that happened along the river. Precipitation represented a crucial variable, which led to a business interruption of three to four days. Of course, this strongly impacts costs, too. (M6, 83)

Changed *cash-in-hand* due to adaptive measures are reported by organization H12. Climate change impacts affect *prepaid expenses* (E1) as well as *equity and liabilities* side for organizations T6 and W4.

Table 2 Overview on reported impacts on balance sheet. Note: Numbers in brackets indicate mentioned impacts in the future

Position on balance sheet	Type of impact	Industry sector							
		H	T	M	W	F	E	C	Σ
		# Organizations							
		13	12	9	9	6	4	4	57
Balance sheet in general	Positive impact	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Negative impact	0 (0)	0 (0)	2 (0)	0 (0)	0 (0)	0 (1)	0 (0)	2 (1)
	Neutral impact	0 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (2)
Fixed assets	Direct impact	0 (0)	0 (0)	0 (0)	0 (1)	0 (0)	1 (0)	0 (0)	1 (1)
	Impact by adapt.	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (1)	0 (0)	1 (2)
Intangible assets	Direct impact	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Impact by adapt.	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tangible assets	Direct impact	4 (1)	4 (0)	3 (0)	5 (1)	0 (1)	1 (1)	0 (0)	17 (4)
	Impact by adapt.	4 (6)	8 (7)	2 (5)	4 (3)	3 (4)	1 (1)	3 (1)	25 (27)
Financial assets	Direct impact	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Impact by adapt.	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Current assets in general	Direct impact	0 (0)	0 (0)	0 (0)	0 (1)	0 (0)	0 (1)	0 (0)	0 (2)
	Impact by adapt.	0 (1)	0 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (2)
Inventories	Direct impact	1 (0)	0 (0)	0 (0)	0 (1)	1 (1)	0 (0)	0 (0)	2 (2)
	Impact by adapt.	0 (2)	2 (0)	0 (1)	0 (2)	0 (1)	0 (0)	0 (0)	2 (6)
Receivables and other assets	Direct impact	0 (0)	0 (0)	0 (0)	0 (0)	0 (1)	0 (0)	0 (0)	0 (1)
	Impact by adapt.	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Securities	Direct impact	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Impact by adapt.	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cash-in-hand	Direct impact	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Impact by adapt.	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)

(continued)

Table 2 (continued)

Position on balance sheet	Type of impact	Industry sector							
		H	T	M	W	F	E	C	Σ
		# Organizations							
		13	12	9	9	6	4	4	57
Prepaid expenses	Direct impact	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	0 (0)	1 (0)
	Impact by adapt.	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Equity/accruals/liabilities	Direct impact	0 (0)	1 (0)	0 (2)	1 (1)	0 (1)	0 (0)	0 (0)	2 (4)
	Impact by adapt.	0 (0)	0 (1)	0 (2)	0 (0)	0 (0)	0 (1)	0 (0)	0 (4)
Σ Direct impacts per position		2 (1)	2 (0)	1 (1)	2 (5)	1 (4)	3 (2)	0 (0)	5 (6)
Σ Impacts by adaptation per position		2 (3)	3 (4)	1 (3)	1 (2)	1 (2)	1 (3)	3 (1)	4 (5)
# Organizations impacted directly, by adaptation, or in general		7 (8)	9 (7)	4 (6)	7 (6)	4 (5)	2 (3)	3 (1)	36 (36)

We are further interested in industry sector specific differences. Organizations of the water and sewage supply industry tend to be most affected, with 77 % of the organizations reporting being affected, followed by organizations of the tourism and construction industry sector (both 75 %). Food and tobacco (66 %), high-tech (53 %), energy supply (50 %), and mechanical engineering industries (44 %) follow afterwards. The same pattern can be seen when regarding the most affected position of tangible assets.

During interviews, we also asked for forecasts or possible consequences. In the future, 61 % of interviewed organizations see an impact on the balance sheet. In comparison to present impacts, only 21 out of 36 organizations which reported on current or past impacts also see future or vague impacts. In contrast, 15 organizations which are currently not affected by climate change see impacts in the future. Forecasts of interviewed experts show fewer climate change impacts (12 organizations), whereas the amount of financial consequences for adaptive measures will increase from the present 25 up to 31 organizations in the future. The same applies to the position of *tangible assets*. Forecasted climate change impacts on tangible assets strongly decrease (17 to 4), but financial impact on tangible assets by adaptive measures will stay at the same level (27 organizations see an impact in the future, 25 organizations report on current impacts). Striking to us are the financial consequences by adaptive measures for *inventories*, as six organizations report on such predicted or vague changes. Climate change might also affect *current assets in general* by direct impacts (E1, W4) and adaptive measures (H12, T6). The last analyzed positions are future or vague changes on the *equity and liabilities* side. There are seven reporting organizations that see changes in equity and liabilities, in comparison to currently only two affected organizations.

5.2 Impacts on Profit and Loss Account

In a second step, we deeply analyzed impacts of climate change on the profit and loss account. In total, 91 % of interviewed organizations see multiple positions of their profit and loss account being affected by climate change. All results of our analysis for affected positions of profit and loss account are listed in Table 3.

First of all, we distinguish between positions of the profit and loss account being affected either by climate change impacts or by adaptation measures. The interviewed organizations list altogether 139 times positions affected by climate change impacts and 61 times positions affected by measures in order to adapt to climate change.

We begin our detailed analysis with the most affected position by climate change impacts: s*ales* were mentioned by 60 % of interviewed organizations. In total, we realized 68 codings concerning affected sales figures. On the one hand, experts from the construction industry, for example, report on positive effects:

> As positive, I would like to mention the position of sales. Since you have talked about the flood, there, we have already had some more orders. This means in fact, sales increased by this. (C1, 98)

Another organization from the food and tobacco industry stated that:

> If I were mean, then I would say right now, the warmer, the better, as people consume more. (F5, 27)

On the other hand, interviewed experts complain on six to eight weeks of sales shortfalls after a flood event (M7, 212–214; M9, 123). To conclude, there are tendencies in both directions, either positive or negative impacts on sales. In addition, organizations from the energy supply industry reported on climate change to have already taken affect in positive and negative manners:

> Yes, climatic phenomena, when there are particularly warmer winters, of course, sales are affected, likewise, when there are cold winters. (E4, 11)

These altered sales figure are followed by altered *energy costs* being part of the position material costs. This second most affected financial figure is mentioned by 40 % of organizations having a climate change impact and by 16 % of organizations as a result of realized adaptation measures. Oftentimes, a climate change impact on energy expenses is a result of higher cooling demand in order to keep proper production requirements (H1, 63; H2, 96; H4, 26–27; H7, 32; C3, 138–139; H8, 32–33; F1, 7, 33, 95; F2, 89; F3, 65–70; F6, 19, 47–48; T8, 136; T9, 227–228; T11, 89). H2, for instance, argues that variation of temperature for the production in

Table 3 Overview on reported impacts on profit and loss account. Note: Numbers in brackets indicate mentioned impacts in the future

Position on profit and loss account	Type of impact	Industry sector							
		H	T	M	W	F	E	C	Σ
		# Organizations							
		13	12	9	9	6	4	4	57
Profit and loss account in general	Positive impact	0 (0)	0 (0)	0 (0)	0 (1)	0 (0)	0 (0)	0 (0)	0 (1)
	Negative impact	0 (0)	0 (1)	2 (1)	0 (0)	0 (0)	0 (1)	0 (0)	2 (3)
	Neutral impact	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (1)	1 (2)
Sales	Direct impact	5 (3)	8 (3)	3 (3)	7 (3)	5 (1)	3 (4)	3 (3)	34 (20)
	Impact by adapt.	0 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (2)
In-/decrease in finished goods inventories and work in process	Direct impact	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Impact by adapt.	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Own work capitalized	Direct impact	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Impact by adapt.	0 (0)	0 (0)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	1 (0)
Material costs (MC)	Direct impact	1 (1)	1 (1)	1 (2)	4 (2)	5 (2)	2 (1)	1 (0)	15 (9)
	Impact by adapt.	0 (0)	1 (1)	0 (2)	2 (1)	2 (0)	0 (0)	4 (0)	9 (4)
Energy costs (part of MC)	Direct impact	6 (3)	5 (1)	3 (5)	4 (0)	4 (2)	0 (0)	1 (0)	23 (11)
	Impact by adapt.	0 (2)	2 (4)	2 (1)	3 (1)	2 (0)	0 (0)	0 (0)	9 (8)
Personnel expenses	Direct impact	1 (1)	3 (1)	2 (1)	1 (0)	0 (3)	1 (0)	3 (1)	11 (7)
	Impact by adapt.	2 (1)	2 (0)	0 (0)	0 (0)	0 (1)	0 (0)	3 (0)	7 (2)
Selling expenses	Direct impact	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Impact by adapt.	0 (0)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)
Depreciations and amortization	Direct impact	0 (0)	3 (0)	0 (0)	2 (1)	0 (0)	0 (0)	0 (0)	5 (1)
	Impact by adapt.	0 (0)	2 (2)	0 (3)	2 (1)	0 (0)	0 (0)	0 (0)	4 (6)
Other operating income	Direct impact	1 (0)	1 (0)	1 (0)	1 (1)	2 (0)	0 (0)	0 (0)	6 (2)
	Impact by adapt.	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

(continued)

Table 3 (continued)

Position on profit and loss account	Type of impact	Industry sector							
		H	T	M	W	F	E	C	Σ
		# Organizations							
		13	12	9	9	6	4	4	57
Other operating expenses	Direct impact	1 (1)	0 (3)	0 (0)	2 (1)	1 (0)	0 (2)	0 (0)	4 (7)
	Impact by adapt.	1 (0)	4 (0)	0 (6)	1 (1)	0 (1)	1 (0)	3 (0)	10 (8)
Insurance costs (part of other oper. expenses)	Direct impact	1 (2)	1 (1)	1 (1)	2 (0)	0 (1)	0 (0)	1 (2)	6 (7)
	Impact by adapt.	2 (1)	3 (0)	3 (0)	3 (0)	1 (0)	0 (0)	2 (0)	14 (1)
Disposal costs (part of other oper. expenses)	Direct impact	1 (0)	0 (0)	0 (0)	1 (0)	1 (0)	0 (0)	0 (0)	3 (0)
	Impact by adapt.	0 (0)	2 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (0)
Operating result	Direct impact	0 (0)	0 (1)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)
	Impact by adapt.	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Income from other participation of which… from affiliated companies	Direct impact	0 (0)	0 (0)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	1 (0)
	Impact by adapt.	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Income from other investments and long term loans, of which… relating to affiliated companies	Direct impact	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Impact by adapt.	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Interest and similar expenses, of which…to affiliated companies	Direct impact	0 (0)	1 (0)	0 (0)	0 (1)	0 (0)	0 (0)	0 (0)	1 (1)
	Impact by adapt.	0 (0)	0 (0)	0 (2)	3 (1)	0 (0)	0 (0)	0 (0)	3 (3)
Result of ordinary activities	Direct impact	0 (0)	0 (0)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	1 (0)
	Impact by adapt.	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Extraordinary income	Direct impact	0 (0)	3 (0)	2 (0)	3 (0)	0 (0)	1 (0)	0 (0)	9 (0)
	Impact by adapt.	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Extraordinary expenses	Direct impact	2 (0)	2 (0)	0 (0)	2 (2)	1 (1)	2 (1)	0 (1)	9 (5)
	Impact by adapt.	0 (0)	0 (0)	0 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

(continued)

Table 3 (continued)

Position on profit and loss account	Type of impact	Industry sector							
		H	T	M	W	F	E	C	Σ
		# Organizations							
		13	12	9	9	6	4	4	57
Extraordinary result	Direct impact	0 (0)	0 (0)	0 (0)	0 (1)	0 (0)	0 (0)	0 (0)	0 (1)
	Impact by adapt.	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Taxes on income	Direct impact	0 (1)	1 (0)	0 (1)	3 (0)	0 (0)	0 (0)	0 (0)	4 (2)
	Impact by adapt.	0 (0)	0 (0)	0 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (1)
Other taxes	Direct impact	0 (0)	0 (0)	0 (0)	0 (1)	0 (0)	0 (0)	0 (0)	0 (1)
	Impact by adapt.	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Net income/net loss for the year	Direct impact	3 (0)	1 (3)	0 (1)	2 (3)	0 (2)	0 (1)	0 (1)	6 (11)
	Impact by adapt.	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	1 (0)
Σ Direct impacts per position		10 (7)	12 (8)	8 (7)	15 (10)	7 (7)	5 (5)	5 (5)	17 (14)
Σ Impacts by adaptation per position		3 (4)	7 (3)	4 (7)	7 (5)	3 (2)	1 (0)	6 (0)	11 (9)
# Organizations impacted directly, by adaptation, or in general		11 (11)	12 (10)	6 (8)	9 (6)	6 (5)	4 (4)	4 (3)	52 (47)

clean rooms is 0.5 °C (H2, 96). Hence, increasing temperature extremes highly affect energy expenses:

> And there is a considerable cost factor, the energy expenses, they are immense. (H2, 96)

In contrast, one expert from the mechanical engineering industry looks for positive impacts because heating expenses decrease during milder winters (M1, 151).

The third most affected position of profit and loss accounts are *material costs (excluding energy costs)*. 15 organizations see climate change impacts, while nine organizations report on adaptive measures that influence material expenses. To list just a few examples for such adaptation measures, organizations of the water and sewage supply industry have to add more chemicals (W2, 112; W7, 279–281); likewise, construction companies require chemical additives or protective foils when they are concreting in extreme heat or extreme cold periods (C1, 95–96; C2, 178–179, 202–204; C3, 123; C4; 220–221, 223).

Insurance costs, as part of *other operating expenses*, also represent a highly affected financial figure. 25 % see adaptive measures and 11 % of interviewed experts discuss climate change impacts that alter the position insurance costs. Experts mainly discuss the idea that newer scientific findings induce insurers to higher insurance rates. For instance, the insurer of organization W5 included higher likelihood of lightning strikes for the distinct region and, therefore, the insurer adapted rates to a higher amount (W5, 126–127). Otherwise, an expert from organization H10 explains that they adapted to the higher risk of lightning strikes by concluding an insurance contract about power outages (H10, 102–105).

A high impact by climate change is also measurable by mainly higher *personnel expenses*. 19 % of organizations report climate change impacts, 12 % list adaptation measures in the context of personnel expenses. In addition, there is a noticeably high impact on the construction industry: two organizations discuss climate change impacts as well as adaptive measures (C1, C3), the other two either climate change effects or impacts by realized adaptation (C2, C4). Reasons are lower productivity (C2, 209; C3, 113–115) or more required staff for realizing adaptive measures such as protective foils or moistening while concreting (C1, 96).

Further pertained positions are, amongst others, *depreciations and amortization* (5 climate change impacts, 4 impacts by adaptive measures), *other operating income* (6 affected organizations by adaptive measures), *other operating expenses* except insurance costs (4 climate change impacts, 10 organizations with adaptive measures), as well as *extraordinary income* and *extraordinary expenses* (both positions with 9 organizations listing climate change impacts). *Depreciations* arise for example from disturbed machines or technical equipment as well as from new machines such as air-conditioning systems. Provided that an organization has an insurance policy and the insurance company paid the insured loss, this money is then registered as *other operating income*. Additionally, several organizations received governmental subsidies after the flood event in 2002, which can be assigned to *extraordinary income*. Unless an organization has no or insufficient insurance coverage and the government subsidies are not enough to cover the extent of loss, then an organization can realize an *extraordinary expense*.

To list just one further example, we consider adaptive measures related to other operation expenses. Here, energy supplier E2 provides free water to the staff (E2, 118–119), similar to organizations H9, C1, and T11 (H9, 120; C1, 93; T11, 89).

Finally, two organizations of the mechanical engineering industry argue that climate change takes negative effects on *profit and loss accounting in general* (M6, M9). According to our results, climate change affects profit and loss accounts in various fields and in both, negative as well as positive, directions.

Considering listed climate change impacts and impacts by adaptive measures as well as general statements, we identify the water and sewage supply industry with the most frequently mentioned affected positions of profit and loss account: 36 mentions for climate change impacts and 15 mentions by adaptation measures divided by nine organizations results in a factor of 5.66. This is followed by the construction industry (factor 5.5), food and tobacco industry (factor 4), and tourism industry (factor 3.83). In contrast, organizations of the high-tech industry reach a factor of 2.07. Hence, positions of the profit and loss account from an average water and sewage supplier are more affected by different climate change impacts and impacts by adaptive measures in comparison to positions of an average interviewed organization in the high-tech industry.

Looking at the future and vague formulated statements, we identify 82 % of interviewed organizations. 41 out of these 47 affected organizations forecast climate change impacts, while 21 organizations report on adaptive measures that will take effect on positions of profit and loss account. We start with *general statements* of three organizations that predict climate change to take an overall negative effect on their profit and loss account (E3, M9, T3), whereas water supplier W6 forecasts positive effects (W6, 78) and C4 as well as T12 talk about balanced impacts of climate change.

Once more, the most affected position by impacts of climate change is represented by *sales* (39 % of all interviewed organizations forecast a future sales impact). 35 % of experts argue for future climate change impacts. Two organizations of the high-tech industry (H1, H5) already predict adaptive measures to affect sales in a positive manner as they adapt to changing market requirements induced by climate change with the development of new technologies and related products (H1, 43, 79–80; H5, 92). Tourism company T4 states that:

> Perspectively, sales would increase. (T4, 131),

mainly due to a possible longer touristic season (T4, 131); on the other hand, organizations have to deal with higher expenses for material, energy, and personnel.

Future changes for *energy costs* as part of material costs are listed by one-third of all organizations; eleven of these organizations report future climate change impacts, the other eight organizations attribute altered energy expenses to adaptive measures. More cooling in summer as well as less heating demand in winter represent the main reasons. Expert of M1 concludes:

> This will be a zero-sum game. (M1, 191)

Future adaptive measures mainly refer to more energy demand for using the air conditioning system more often (e.g. W2, 114; T4, 133–136; H9, 107).

In contrast to reported past or current impacts on *other operating expenses* excluding insurance costs, in the future, more organizations see climate change impact on this position of the profit and loss account (7 organizations in comparison to 4). These higher expenses will primarily arise from higher maintenance efforts (E1, 151; E3, 144–145; T1, 156–159; T5, 190; T9, 229–230). Impacts on *other operating expenses* by adaptive measures will decrease from ten to eight reporting organizations.

Future *material costs* represent the fourth most affected position as 19 % of all interviewed organizations report on such impacts by climate change. In comparison to current or past reported impacts, climate change impacts (15 current mentions to 9 in the future) as well as impacts by adaptive measures (9 current mentions to 4 in the future) on material costs will decrease.

Analysis results in the same tendency of lower impacts by climate change for future *personnel expenses* as well as the position of future *insurance costs* as part of other operating expenses.

One noticeable change concerns the position of *net income/net loss for the year*. For the future, there are more experts (19 %) talking about climate change impacts on annual net profit. F1 argues that higher future expenses such as for energy cannot be directly passed to the customer, hence, net income will decrease as the margin decreases, too (F1, 95).

Finally, we also calculated a factor of climate change impacts and impacts by adaptive measures as well as general statements divided by number of organizations per industry sector. Here, we identify industry sector of mechanical engineering with the highest factor of 3.44 since analysis revealed 14 mentions for climate change impacts and 16 mentions by adaptation measures as well as one general statement. Energy suppliers and construction companies follow with a factor of 2.25 and 2.0. High-tech industry comes last with a factor of 1.38. Hence, in the future, other industry sectors (mechanical engineering and energy supply) might have more affected positions on their profit and loss account. However, the magnitude and likelihood of reported future impacts are not included in our analysis.

In conclusion, our analysis shows different positions of the balance sheet and the profit and loss account influenced by climate change impacts and related adaptation measures.

We identify that especially the tangible assets are affected by climate change impacts and climate change adaptation. Damages to buildings and technical equipment resulting from extreme weather events and, thus, depreciations (Bakhshi and Krajeski 2007) were mentioned mostly by organizations similar to the investigation by Busch (2011). Changes arising from climate change adaptation focusing mostly on new investments, for example in air-conditioning systems. Contrarily, liabilities were only mentioned by a few companies, which can be reasoned by the non-investigation of the insurance industry. Additionally, we identified that the following positions are affected by climate change impacts and climate change adaptation: intangible assets, cash-in-hand, and prepaid expenses. As mentioned above, we only considered those positions mentioned by the organization without transferring them to the balance sheet and vice versa. Following Bakhshi and Krajeski (2007), who explain that insurance costs affect the current assets or the cash positions, we also observed this effect.

Similar to the literature (e.g., Botzen et al. 2010; Wedawatta et al. 2011), we have found that especially the position sales is affected by climate change impacts; but contrary to the literature, we could also observe positive influences arising from climate change impacts. Contrary to the literature, our interviewees mentioned several times the influences on energy costs as part of material costs arising from climate change impacts and climate change adaptation. Mostly, organizations observe negative effects due to increasing energy prices, decreasing demand, or due to additional air-conditioning systems. However, due to milder winters a few organization expect decreasing energy costs. Similar to Busch (2011) we identified higher material costs because of the use of additional materials and changed insurance costs due to higher insurance premiums in consequence of an extreme weather event or the decision to finalize an insurance contract. Lower productivity was also the main reason for increasing personnel expenditures as already Wedawatta et al. (2011) stated. But also additional expenditures in order to realize adaptation measures were one mentioned reason for an increase of this cost position. Additional to the literature, our interviewed experts mentioned depreciations, other operating income, other extraordinary income, and extraordinary expenses.

We can conclude that the profit and loss account is in the first instance rather affected by climate impacts and adaptation measures in comparison to the balance sheet. However, both financial reporting instruments are closely intertwined (Coenenberg et al. 2007), and during our analysis, we only coded the primary impact mentioned by the interviewee. Hence, in a second step, impacts on the balance sheet are noticeable, too.

Moreover, we can currently observe more climate change impacts than impacts by climate change adaptation. This can be explained by a noticeable sum of organizations which have not realized adaptation measures so far.

6 Conclusion

Climate change already financially affects organizations in various ways. The findings of the conducted content analysis present the empirical proof that corporate finances are affected by climate change impacts as well as by climate change adaptation. The examination of 57 in-depth expert interviews from seven different industry sectors determines several impacts on balance sheets and profit and loss accounts across all industry sectors investigated.

The first limitation of our analysis is that the analyzed organizations originate from one distinct region in Western Europe. Hence, the transferability of results to organizations in other developed or even developing countries is not provided. Besides the quite limited sample, the analysis only considered the change in financial indicators on balance sheets and profit and loss accounts. Furthermore, this study does not address aggregated indicators as a measurement tool for financial performance. Thus, the emphasis on determining the source of impacts on financial indicators presents a second limitation. Therefore, future research strongly necessitates the exploration of further financial indicators and even more specific data from even more varied industry sectors. Research continues to require access to sensitive data in order to determine business challenges of climate change.

By realizing this in-depth analysis, we answered which financial positions of the traditional financial accounting are affected by climate change impacts and related climate change adaptation measures. Thus, we analyzed the traditional cost accounting system and identified hidden costs of organizations which would not arise if an organization would not be vulnerable to climate change. However, in most cases organizations do not analyze these costs in detail. For future research, we firstly suggest a similar study for the outside-in perspective. Secondly, to consider the monetary climate management accounting perspective, we recommend to analyze more deeply if and how organizations decide for mitigation or adaptation measures. For those decisions, the Net-Effect can be used, which considers three different cost categories: action costs, transferable costs, and opportunity costs. Looking at the outside-in perspective, action costs encompass the costs for adaptation measures. The second group of costs can be transferred to a third-party, for example to the supplier or the consumer. Consequences of third parties, for example taxes or penalties, can be assigned to opportunity costs. Moreover, organizations have to consider increasing insurance costs or decreasing sales in consequence of an extreme weather event. Based on this Net-Effect, organizations can decide if they react rather anticipatorily or reactively. In a third step, we propose to consider the environmental impacts of mitigation and adaptation measures by realizing a life cycle assessment and, thus, to consider the non-monetary perspective of climate financial accounting and climate management accounting or of climate vulnerability accounting and carbon accounting, respectively.

To give this research agenda a suitable framework, we suggest to take up the three-stage model of Guenther and Guenther (2003) considering ecological resources within accounting with the aim to control these resources. Stage 1 of the framework —***Differentiated Value Added***—comprises the monetary part of climate financial accounting. Our conducted analysis belongs to this first level (monetary, external, adaptation). The above described Net-Effect can be included in the second stage of the framework—***Adjusted Value Added***—to decide for or against a response option and, thus, it includes the monetary climate management accounting. The realization of the Adjusted Value Added implies that the resources can be assessed monetarily, which is not possible in all cases. Therefore, at stage 3 of the framework—***Extended Value Added***—the non-monetary assessment of measures can be realized in order to consider the non-monetary perspective of climate financial accounting and climate management accounting or of climate vulnerability accounting and carbon accounting, respectively. However, in order to bring this proposed three-stage model into the organizational mindset and decision making, there is still a long way to go and will require more efforts—by scientists and practitioners.

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Carbon Emission Accounting Fraud

Shamima Haque and Muhammad Azizul Islam

Abstract This chapter explores the motivation behind potential carbon emission accounting fraud by corporations. There are several different possible risks of carbon emission accounting fraud which remain mostly overlooked by researchers to date, despite the fact that such frauds have a negative impact on a country's economy as well as the real purpose of mitigating carbon emissions. The chapter offers discussion of some potential risks of carbon emission accounting fraud as well as related prevention policy. The study suggests that an effective mandatory carbon emission related fraud prevention policy is essential to eliminate opportunities to commit such fraud by corporations.

1 Introduction

In recent years, climate change has drawn attention in the international scientific and policy arenas, to the extent that it is now considered to be the most important global environmental issue that the 21st century is facing. As the science of climate change has continued to evolve, increasing evidence of anthropogenic influences on climate change has been found. Correspondingly, the Intergovernmental Panel on Climate Change (IPCC), a group established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), released a number of authoritative reports about human impacts on the Earth's climate, which ultimately led to the development of the Kyoto Protocol in 1997. Among the human influences noted, the business community is largely responsible for many of the causes of global climate change, and at the same time, it will also be

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affected by the potential risks associated with it. There are differential risks that climate change poses on businesses, which in turn, can affect their profitability and value, and even threaten their survival and accountability (Carbon Disclosure Project 2008; CERES 2002; Labbat and White 2007; Rolph and Prior 2006; Bebbington et al. 2008). Apart from risks, climate change has also provided potential business opportunities through projects that reduce greenhouse gas (GHG) emissions, such as the development of more efficient and alternative energy supplies, reduced petroleum dependence, and the trading of carbon credits in the energy market (Southword 2009; Martin and Walters 2013). However, such opportunities can also create a risk of climate change fraud. There is increasing evidence of climate change fraud being reported in the media. For example, there are reports of widespread fraud in trading in the European Union Emissions Trading System (EU ETS) and in the production and sale of carbon credits from carbon abatement projects (offset projects) (Lohmann 2010).

This chapter offers discussion of some of the potential risks of carbon emission accounting fraud as well as related prevention policies. There are several different possible risks of carbon emission fraud which remain mostly overlooked by the researchers to date, despite the fact that such frauds may have a negative impact on a country's economy as well as the real purpose of mitigating carbon emissions. While relevant carbon emission frauds include, among others, carbon investment scams, transactional frauds, and accounting and reporting frauds, this chapter provides an extended discussion of carbon emission accounting fraud. In particular, we explore the motivation behind potential carbon emission accounting fraud by corporations. The study suggests that an effective mandatory carbon emission related fraud prevention policy is essential to eliminate opportunities to commit such fraud by corporations.

2 Major Carbon Emission Schemes: An Overview

From the IPCC to the Kyoto Protocol, there is an imperative objective of controlling the human impacts of global GHG emissions within a certain benchmark. Carbon credit trading is one such initiative that is used by different nations across the globe. It is a cap and trade system for carbon dioxide (CO_2) emissions certificates. A limit (or 'cap') is set for countries or companies on the total amount of GHG emissions they can produce. If they exceed the limit they are required to buy carbon credits from others. Those with surplus carbon credits may sell them to emitters that require more (the 'trade'). Thus carbon trading gives an incentive for major emissions-intensive companies to reduce their emissions. As the market grows, companies may maximise the value of their carbon credits. It is reasonable to predict that if a company reduces its emissions, while simultaneously increasing its profits, it will be motivated to continue to do so; however, this is not always the case.

The global carbon market is now estimated to be worth approximately $118 billion (Deloitte 2009). Carbon can be traded in two markets: the regulated market (ETS) and the voluntary market (unregulated market). While the EU ETS is by far the world's biggest carbon market, and fundamental to the international carbon market, the number of carbon emissions trading systems around the world is increasing. Besides the EU ETS, national or sub-national systems are already operating in Australia, Japan, New Zealand and the United States, and are planned in Canada, China, South Korea and Switzerland (Climate action 2012). There are a number of other national and regional carbon markets that have been, or are in the process of being, developed or expanded. For example, the New Zealand Emissions Trading Scheme (NZ ETS), the New South Wales Greenhouse Gas Abatement Scheme (NSW GGAS), the Regional Greenhouse Gas Initiative (RGGI) New York, the Western Climate Initiative (WCI) Québec, and so forth. Many countries are also seriously considering the EU ETS as a model for their possible permanent trading scheme. For example, the Australian Government introduced an emissions trading scheme (also known as the Carbon Pricing Mechanism or CPM), which started on July 1, 2012. CPM became law in November 2011 as the Clean Energy Act (2011) which required the CPM to start with a three-year fixed price period (2012–2015) and then transition to a fully flexible interim one-way link between CPM and the EU ETS in July 2015, with a full two-way link by July 2018 (Carbon Spectator 2013; Interpol 2013; International Carbon Action Partnership 2014). However, in light of new developments in Australia[1] subsequent to the government change in September 2013, bilateral linking talks are currently on hold (International Carbon Action Partnership 2014).

Carbon emission is also connected to the developing nations through the Kyoto Protocol's Clean Development Mechanism (CDM). CDM is one of the flexibility mechanisms defined in the Kyoto Protocol (IPCC 2007) that provides for emissions reduction projects which generate Certified Emission Reduction (CER) units which may be traded in emissions trading schemes (IPCC 2007). CDM provides a way of transferring financial and technological resources to developing countries in exchange for emissions reductions. The CDM, and the associated generation of CERs, are an essential component (in the form of marketable securities) in the efficient and effective functioning of cap and trade markets (Drew and Drew 2010). These markets, such as the EU ETS, allow for price discovery to occur resulting in a market price for carbon (Drew and Drew 2010). Integrity issues, real or perceived, resulting from the potential for fraud and/or deception in market-based mechanisms such as the CDM are of paramount importance to all stakeholders to ensure a meaningful, sustained response to the challenges of climate change (Drew and Drew 2010).

[1]On September 7, 2013 a new Government was elected with a policy to repeal the CPM and replace it with a Direct Action Plan. On November 13, 2013, the Government introduced draft legislation to repeal the Carbon Pricing Mechanism. Until the re-peal legislation passes both Houses, the CPM will remain law (International Carbon Action Partnership 2014).

3 Carbon Emissions Fraud

While carbon trading systems, set by regulators as discussed (EU ETS for example), aim to benefit the economy as well as preserve the environment for future generations by reducing emissions, trading systems do offer potential negative effects which cannot be ignored. In contrast to traditional commodities, carbon credits do not represent a tangible product which can be delivered to a consumer; instead they can be described as a '*legal fiction*' that is poorly understood by many sellers, buyers and traders (Interpol Environmental Crime Programme 2013). Due to this limited understanding, carbon trading is often vulnerable to fraud and other illegal activity. Like other financial markets, carbon markets are also at risk of exploitation by criminals due to the large amount of money invested, the immaturity of the regulations and a lack of oversight and transparency (Interpol Environmental Crime Programme 2013).

The Interpol Environmental Crime Programme lists five categories of illegal activities in carbon markets: fraudulent manipulation of measurements to claim more carbon credits from a project than were actually obtained; sale of carbon credits that either do not exist or belong to someone else; false or misleading claims with respect to the environmental or financial benefits of carbon market investments; exploitation of weak regulations in the carbon market to commit financial crimes, such as money laundering, securities fraud or tax fraud; and computer hacking or phishing to steal carbon credits and theft of personal information (Interpol Environmental Crime Programme 2013). According to the Interpol report, carbon credit projects provide opportunities to fraudsters to manipulate measurements and dishonestly obtain a greater allocation of carbon credits, either by overinflating the estimate of the emissions or by fraudulently claiming that the project reduces emissions to a greater degree than it actually does. On the other hand, the intangible nature of carbon credits also makes it possible to separate ownership in the carbon rights from the physical project; for example, a project may be owned and managed by one person or company, while another acquires the legal rights to trade in any carbon credits generated. The risk of corruption, therefore, is increased by the fact that there is no physical indication of the identity of the person who holds the carbon rights, beyond a piece of paper or record in a government register. Also, because of the lack of understanding among traders and buyers about how the carbon markets operate, companies can take advantage of the paucity of expert knowledge, with many examples of advertising campaigns or investment advice that involves false and misleading claims. Poor legal regulation, together with the lack of any tangible asset behind the traded carbon credits, makes this market perhaps even more vulnerable to exploitation in the form of Value Added Tax (VAT) scams, money laundering and securities fraud. National registries have been established to keep a record of all carbon credits under the mechanisms of the Kyoto Protocol (UNFCCC 2011). However, weaknesses in the internet security of these registries have been exploited by criminals who have been able to steal carbon credits. Also, the electronic nature of carbon credits and their registries makes the carbon trading market particularly susceptible to technology crimes such as hacking.

The media frequently reports news about frauds and scams related to carbon credit trading (ACCC 2013). Specifically, these news reports often refer to carbon trading fraud cases around the globe (including the UK, EU and Australia). One of the most notorious scams which occurs in the EU market is the VAT scam. As explained by Singh (2009), the VAT scam occurs when a company sells a carbon credit to another company. According to the regulations, both companies should pay VAT; however, in this scam, after the buyer pays VAT, the seller declares bankruptcy, avoids paying the tax, and the buyer can then claim the VAT back from the tax authority. Later, the buyer can then re-sell the carbon credits to overseas buyers who are not liable to pay VAT. These kinds of carbon credit scams were reported to be worth more than €1.5 billion (in five European countries) and £38 million in the UK (Deloitte 2009). In 2010, a number of investigations of carbon credit scams, in particular those related to VAT fraud, took place in Europe (Interpol Environmental Crime Programme 2013). This resulted in hundreds of raids on European offices and over 100 arrests in relation to VAT fraud within the EU ETS (Interpol Environmental Crime Programme 2013). The EU trading market, as the first to implement an ETS scheme, made a loss of €5 billion from tax fraud on carbon credits, as well as a loss of €33 million from a series of other fraudulent activities within the ETS regulation system (Jeffries 2012).

As the size and value of the carbon markets grows, the amount of fraud taking place can be expected to rise. For example, one particular type of fraud being investigated in the EU involves buyers importing carbon permits in one EU country (without paying VAT), and then selling them in another, adding tax to the selling price and pocketing the difference. A specific example is an incident involving six traders in Germany, who were accused of evading over €200 million in VAT in the European carbon market between September 2009 and April 2010, taking advantage of German tax regulations which were valid only until April 2010 (Reuters 2011). The penalty for this kind of crime is possible prison terms of up to nine years. In another example, during 2013, in the UK, 19 companies sourced investment of nearly £24 million from over 1500 people (including many elderly people) by selling carbon credits in the manner of shares or bonds (The Guardian 2013). These small investors were promised significant returns for permits, each worth the emission of one ton of CO_2. While each permit was relatively expensive for the individual purchasers, they were too small to attract interest from large companies, who generally trade CERs in bulk quantities (The Guardian 2013).

Another example comes from the UK, where three defendants were found guilty of carbon trading carousel fraud and jailed for a combined total of 35 years in 2012 (Interpol Environmental Crime Programme 2013). The three individual traders defrauded the VAT system by setting up bogus companies, which imported carbon credits into the UK, and were then dissolved after the carbon credits were sold. At that time the carbon credits were resold to other ‘buffer’ companies, which were also organised by the three individuals (to make the trading chain appear legitimate), and finally to legitimate companies, charging VAT which was never paid to the government. This occurred in 69 days of trading and generated €276 million (including €41 million worth of VAT). These trades were completed online within minutes. The stolen VAT was sent to bank accounts in the United Arab Emirates, and the money was later spent by the group (Interpol Environmental Crime Programme 2013).

In a non ETS country such as Australia, the most common fraud occurring in the *voluntary* carbon market is false carbon investment scams. One famous case is that of the Western Field Holdings Inc. (WFH). WFH is a telemarketing organisation from overseas which targeted Australian consumers and businesses seeking investment in carbon credits. WFH acted on behalf of an investment scam business based in Japan, which then contacted the Australian individuals who expressed interest in investing in projects that generated carbon credits. The victims of the scam were typically people with a strong environmental interest, limited knowledge of carbon credit trading, and seeking investment opportunities. WFH sourced the investment through an apparently genuine website and 'investment certificates'. When some of the victims later discovered the certificates were fake, and requested their money be refunded, WFH took no action. Ultimately investigators found that more than AUD $3.5 million was invested by Australians in the "projects", and this was sent via major banks (and remittance services) to accounts in Taiwan and China. Australian regulatory authorities have made public statements about WFH and have advised investors to avoid dealing with this company (AUSTRAC 2011). In a similar case (in 2009–2010), another company conducted an aggressive telemarketing campaign in Australia, claiming false connections with legitimate organisations as well as environmental standards. In this example, the investors were again offered a high return investment opportunity in carbon credits. The claims by this organisation were shown to be false, and that particular company is estimated to have defrauded Australian victims of $3.2 million (SCAM Watch 2012; Fogerty 2010).

In another case in Australia in early 2010, an energy company that was part of the Government's *Global green programme* designed to encourage home owners to use green power, was investigated by the Australian Competition and Consumer Commission (ACCC) who took action against the company (Interpol Environmental Crime Programme 2013). Under the government programme, the company accepted (additional) payments from customers in return for promising to purchase renewable energy certificates (carbon credits) on their behalf. Following the investigation, the ACCC found the power company had not purchased as many carbon credits as it had promised to its customers. The company was forced to purchase the extra credits, and was eventually deregistered from the Global Green programme. The Acting ACCC chairman at the time, Michael Schaper, commented:

> These are markets where consumers don't fully understand what's on offer to them, businesses are still coming to grips with what they can and can't do, and regulators are still grappling with how consumer's expectations are matching up with promises from business (Thomson 2010).

Apart from tax fraud, other carbon frauds, such as transactional frauds, occur during transactions between parties and include money laundering, intentional round-trip transactions and consumer fraud, and so on (Deloitte 2009). Since trading and blending is forbidden currently in the regulated market, we have found no cases related to those frauds. For this reason, the implementation of relevant prevention policies is necessary to avoid fraudulent activity in the future. The Australian Government has apparently taken note of the seriousness of potential fraud in this area, and some cautions have already been issued by specialists in the forensic industry. Consumer fraud is another type of risk which companies, especially those in the tourism, hospitality and leisure industries, are at risk of exposure to. This could happen when those companies enter into arrangements with third-party partners to offer individual customers the opportunity to purchase carbon offsets by means of reducing the environmental impact of their travel (Deloitte 2009). The risk of fraud by air travel companies, on cost estimation of an offset, does exist, and currently occurs in some countries. There could also be a potential risk of collusion between a company and a third party to set the price of a carbon offset higher than is necessary (Walter and Martin 2012).

While most of the carbon trading frauds have so far been evident in developed nations (under the EU ETS), developing countries are also at risk, especially within CDM projects. There are stakeholder concerns about organisational fraud in many CDM projects in the developing world. Many believe these projects are misrepresented and some projects are run or become profitable at the expense of the broader community, or even by contributing to global warming. An important example is the CDM Mega Dams projects in Sikkim. The state of Sikkim, known as the land of rhododendrons, is extremely picturesque, and is located in the Himalayan foothills in India's North East. In Sikkim, rivers have been aggressively dammed over the last decades (Yumnam 2013). Dam developers have attempted to promote these projects as clean energy sources to seek carbon credits as additional profits from the UN CDM (Yumnam 2013). More than fifteen mega hydro projects are already seeking carbon credits in Sikkim, where hydropower is a common energy source. Many are of the opinion that some of these decisions should be reversed, and that no further projects should be approved. As Yumnam (2013) stated:

> The dams in Sikkim are not green and clean and will only worsen global warming if their credits are used to comply with emission reduction obligations. At the same time they will destroy the backbone of livelihood support for millions. Most dam projects ignore the recommendations of the World Commission of Dams (WCD) and the recommendations of the UN Committee on Elimination of Racial Discrimination in 2007 to respect indigenous people's rights in dam construction in India's North East. All validation and registration of big hydro projects for CDM from Sikkim and other parts of India's North East should therefore be revoked immediately and no new projects approved. Indigenous peoples' rights in Sikkim must be fully recognized in all development policies and projects.

In summary, there are a number of different types of carbon fraud and scams that are evident However, most carbon frauds are complex in nature and often difficult to detect. While there are various types of carbon frauds, research has identified emissions reporting as an increasing area of fraud risk (Deloitte 2009; Lindquist and Goldberg 2010). For example, one of the common ways to manipulate credit measurements is to intentionally misreport the data, meaning that the analysis is distorted by measuring only certain variables, a selective choice of sites for collecting data, or adopting certain assumptions in the calculations (Interpol Environmental Crime Programme 2013).

3.1 Nature of Carbon Emission Accounting and Reporting Fraud: A New Nature of Fraud

Misrepresentation and fraudulent reporting of emissions by liable companies is one of the significant risks that exists in the carbon trading market (Goldberg 2010). While only a small number of cases can be found to support the existence of emissions misreporting, this area is the most susceptible to fraud, and this has attracted a considerable amount of concern from different groups (Walter and Martin 2012). Craig Mackenzie, sustainability director at Scottish Widows Investment Partnership, found that even the mandatory emissions data issued by EU companies was incomplete, scattered, often confusing and time-consuming to find (Jeffries 2012). The risks of data misreporting and related frauds are even higher in the case of voluntary carbon emissions reporting, where there is a lack of unified reporting standards for companies.

Reporting of emissions is required because if a company is not monitored in a particular period, its report is the only available information on its emissions which can be used to determine how many permits are used for current compliance and how many are carried into the next period (Stranlund et al. 2005). Companies should, therefore, provide full disclosure of emissions and accounting policies voluntarily to ensure that the financial effects of using emission rights and related contracts are understood (Lindquist and Goldberg 2010). However, some companies dishonestly misreport the real emissions figure due to financial pressures (Deloitte 2009). Through under-reporting of emissions, they can understate the actual carbon credits used to overstate income and asset values (Deloitte 2009; Lindquist and Goldberg 2010). Alternatively, through increasing the baseline of carbon emissions they can gain additional carbon credits, and produce fewer emissions over the pre-established baseline (Lindquist and Goldberg 2010). By doing so, they can save some unused credit and bank or sell it later to make a profit. This would result in an underestimation of emissions and less permits being surrendered to government.

There is also the chance of over-reporting of carbon emission purchases which reduces investments in carbon reduction mechanisms (Lindquist and Goldberg 2010). For example, in countries such as Russia, China, India, and Brazil, there are so-called environmental projects built specifically for the sake of generating emission reduction credits. While some of these ventures are semi-legitimate, others are pure scams to generate profits. Companies can, therefore, purchase these emission credits and claim exaggerated carbon reductions (Lindquist and Goldberg 2010). Sometimes companies even disclose their emissions performance normalised by revenue, employee or floor space, so that it seems to have improved, even if absolute emissions have increased over the years (Jeffries 2012).

Following is an example of carbon accounting fraud, as reported by the Interpol Environmental Crime Programme. In 2008 and 2009 respectively the United Nations (UN) temporarily suspended two independent carbon-accounting organisations—Norwegian company Det Norske Veritas and Swiss firm SGS, after random checks revealed flaws in their accounting methodologies, such as inadequate oversight of their CDM audits and insufficient training and qualifications of their auditing staff (Global Witness 2011; INTERPOL Environmental Crime Programme 2013). At the time of the suspension, the two companies were major stakeholders in validation and verification of approved projects. It was found that projects had been approved by the companies without being scrutinised. One of the companies had a flawed review process, and inadequately qualified auditing staff. The other company was also found to be using staff without the necessary skills and sub-standard internal reviews. The temporary suspension of the two companies was a significant move by the UN to oversee the activities of the Designated Operation Entities (DOEs), however, it also demonstrates that the UN is limited in its ability to monitor these kinds of companies. In this instance, the UN had to rely on the data provided by the DOEs when undertaking the investigation. Random checks found that the activities performed by the companies were office-based, not field-based, adding to the unreliability of the data. This problem is set to continue with the increasing number of projects taking place in remote areas across the globe and the limited capacity of the UN to properly monitor those projects. A review in 2009, of the validation process used, undertaken on behalf of the World Wildlife Fund International, and the Öko-Institut, a Berlin think tank, found that the performance of the five largest DOEs could not be rated better than a score of D on an A-to-F scale.

Within the context of a developing nation, there is also a risk of carbon emissions accounting and reporting fraud. The CDM projects in developing nations enable firms and governments in the developed world to buy credits which allow them to continue emitting GHGs. These are sold to them, through well-rewarded brokers, from companies in developing countries that can show that they have nominally reduced their emissions (Booker 2010). This is concurrent with the notion that there should be appropriate levels of transparency about CDM projects (Kruger and Egenhofer 2005; Drew and Drew 2010). There also needs to be avoidance of insulation from the perpetration of deceptive or fraudulent acts to allow for consideration of the validity of the information itself.

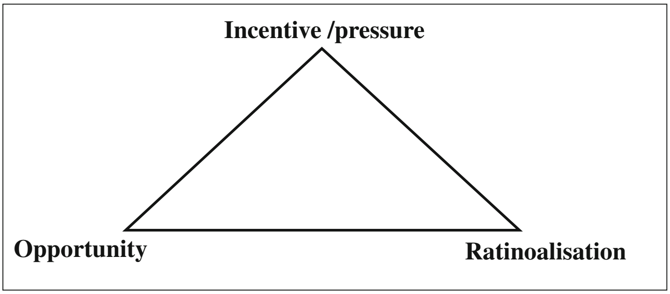
For instance, the regulator within the current CDM system, in most instances, relies on self-reported data. Given this, it is not enough to rely on simply the apparent transparency of information as sufficient insulation against fraudulent or deceptive behaviour. The regulator must have access to a system that is able to check self-reported data and have sufficient powers to institute penalties against those who seek to falsify information (Kruger and Egenhofer 2005; Drew and Drew 2010).

Misreporting of emissions would also have implications at a firm or industry level. For example, the emitter that underreported emissions would be placed at a competitive advantage vis a vis other market participants, as they would need to surrender fewer permits (BarnbyisRight 2011). This advantageous position would be a result of non-compliance with the law rather than legitimate business practices and could entail significant costs for competing companies (BarnbyisRight 2011). This would also have implications for the accuracy of national emissions estimates and would represent an effective loosening of the cap (BarnbyisRight 2011). This occurs frequently during the early stages of regulation (Lindquist and Goldberg 2010). This kind of fraud is also very difficult to audit and expert knowledge is often required. According to Lindquist and Goldberg (2010), “Pollution measuring equipment is very technical and a dedicated fraudster can miscalibrate gauges and meters to give false carbon readings.”

4 Motivation for Carbon Accounting Fraud

Carbon emission accounting fraud can be explained by the fraud triangle model proposed by Cressey (1953). According to Cressey (1953), regardless of the many ways to commit fraud, there are generally three common elements that make up what is known as the fraud triangle (Cressey 1953; Albrecht et al. 2014, p 34). These three elements of the fraud triangle are *perceived pressure* (financial, vices (e.g. drugs, alcohol, gambling), work or other), *perceived opportunity* (wider scope to commit fraud, conceal fraud or avoid being punished, for example, weak policy or internal control systems) and *rationalisation* (being able to justify the fraud in some way, for example, ‘I am underpaid by the employer’).

Diagram: Cressey’s (1953) fraud triangle lens



Among these three elements of the fraud triangle, perceived opportunity is the most important one (Albrecht et al. 2014, p 51). Albrecht et al. (2014) claim that without opportunity fraud cannot occur, and hence it is the opportunity which is the central focus of this chapter, as carbon emission accounting fraud can be controlled if the scope of opportunity for such fraud to take place is limited.

The key opportunities for carbon accounting fraud appear to be due to:

(a) Inadequate internal policy framework and control and auditing systems for effective carbon fraud detection.
(b) Weak regulation of emissions-intensive companies, despite some international and national guidelines to eliminate carbon trading fraud. The carbon-trading market has opened the door to fraud, profiteering, and scamming by participants. The main reason behind this risk of fraud lies within the existing regulatory system. Because of the lack of regulation or weak regulation, and limited enforcement agencies for both verifiers and carbon offset providers, there is a high risk of fraud in these voluntary carbon markets (Buckstein 2009).
(c) The problem of the weak regulatory system, together with the problem of insufficient unified codes and standards in place that can be used as a guide to measure emissions accounting or auditing to ensure consistent quality (Buckstein 2009).
(d) Inadequate fraud awareness training for employees and managers.
(e) The opportunity for fraud arising as the carbon emissions market is new, controls are untested and often large amounts of money are at stake (Chris 2011). It can be seen in the EU market, or even the Australian market, that the roll out of new government schemes are a draw for people and groups seeking to improperly benefit. The issue here is not about the environment or the validity of carbon tax or ETS, but rather about providing another opportunity for fraudsters to commit fraud.
(f) The lack of any tangible asset behind the traded carbon credits. This makes the market perhaps more vulnerable to exploitation. This is of particular concern with the development of new financial products which have not been adequately vetted, and with regulators whose technical knowledge and resources are limited (Interpol 2013).
(g) The difficulty in tracing the movements of carbon credits. It is anticipated that in the near future, carbon credits may be generated in one country, widely sold to persons in another, and traded through several carbon exchanges before reaching the hands of the final owner. The more countries involved, the harder it is to trace the carbon credit from its origin to final purchaser, and the easier it is for fraudsters to take advantage of any legal loopholes or inconsistent regulations between different national legislation (Interpol 2013).
(h) The lack of harmonised tax and VAT regimes across certain regions (such as the EU member states). This can provide a potential cause for fraud.
(i) The limited ability of law enforcers and regulators to work outside their own domestic legal jurisdiction, making enforcement of international carbon markets complicated and difficult without a proper global enforcement response (Interpol 2013).

(j) The differing requirements for carbon trading across different jurisdictions, some more stringent than others. Because there is limited understanding of these multiple standards, there is an increased risk of exposure to fraud (Buckstein 2009).
(k) The lack of mandatory reporting requirements. There is also no explicit penalty for carbon emissions reporting violations under current reporting requirements. Therefore companies are tempted to misreport their emissions information.

Other elements of the fraud triangle, such as perceived pressures and perceived rationalisation, should not be underestimated. An example of a perceived pressure would be the financial stress a company may experience if it produces significant emissions, and the large expense of purchasing sufficient carbon credits. In relation to rationalisation, a company may rationalise its behaviour by seeking excuses for it (such as, the belief that the money contributed is not used for reducing GHG emissions, rather, is being pocketed by government officials); or, the belief that it is in the shareholders' best interests (that is, profit will be maximised) if the fraudulent activity is carried out.

5 Possible Ways to Curb Opportunities for Carbon Accounting and Reporting Fraud

We believe if regulators are able to limit opportunities for carbon accounting fraud, as mentioned earlier, the risk of general carbon emission fraud occurring will be substantially reduced. We are not arguing that currently there is a lack of regulation in place to control carbon accounting fraud within or beyond the organisational level. Rather, for example, in Australia, under the National Greenhouse and Energy Reporting Act (NGER) (2009), significant powers have been given to the regulator to enter and audit relevant premises of liable corporations and to compel the provisions or regulations of the Act (NGER Act, Sch. 73A). There is also a case for imposing penalties for violation of carbon trading provisions. In 2009, the biggest clean energy auditor in the world, SGS UK, had its accreditation suspended by UN inspectors, because it did not properly audit projects in carbon trading markets (Environmental Leader 2010). Although there are laws and regulations set by the government, they do not necessarily prevent fraud. There is a need for effective security and anti-fraud measures for emissions trading. The responsibility of carbon trading regulators in different nations, apart from administering legislation, is fulfilled through auditing, compliance and enforcement of emissions reporting standards. There should be a specific and comprehensive auditing legislative framework to undertake GHG and energy audits. There is a view that while detailed information on auditing methodologies has been provided by the regulator, liable corporations are chosen for audit and the extent of examination of the emissions reports from liable corporations is not apparent. While there is doubt that a country's legal enforcement agencies, including local police, would be required to play a role in regulating emissions trading, there should be a defined responsibility for the law enforcers in validating, monitoring and penalising offenders, given the enormous scale of carbon emissions fraud.

Within the context of developing nations, in relation to CDM projects, an essential step in minimising or at the least, limiting the opportunities for fraud, corruption and/or deception must involve ensuring that verifiers and certifiers are independent assessors (Chan 2009; Drew and Drew 2010). This system of fraud detection may also prove potentially valuable in CDM governance (Drew and Drew 2010).

In order to create real accountability and transparency, corporations as well as regulators need to consider carbon governance and reporting as seriously as financial reporting. While in the voluntary carbon market there are 10 different standards that can be used for the verification of carbon offset credits, and each has different requirements, some more stringent than others, there is limited understanding of these multiple standards, and this creates an increased risk of exposure to fraud (Buckstein 2009). There needs to be uniform carbon reporting guidelines across the globe, and at the same time, there should be explicit penalties for misreporting of carbon emissions under current reporting requirements. While creating enforcement of emissions reporting is the responsibility of the regulators, the capacity of the regulators in different jurisdictions differs significantly. There must also be adequate capacity building training facilities for the regulators of different jurisdictions.

6 Conclusion

This study explores the motivations behind corporate carbon emissions accounting fraud. The study suggests that effective mandatory carbon emissions related fraud prevention policy is essential to eliminate opportunities to commit frauds by corporations. Effective monitoring and auditing mechanisms are essential to eliminate misreporting of carbon emissions. While specialised audits should be imposed by regulators, the reliability of auditing itself is more essential, but also hard to detect. There should be a separate specific law or act (similar to the UK Bribery Act 2010, which is a specialised law to curb bribery) which may help in the prevention of fraudulent reporting and misreporting of carbon emissions. While there should be a uniform standard across the globe, mandatory auditing and reporting requirements should at least be in place to limit carbon emissions fraud globally.

More research is needed to investigate those areas and aspects of carbon emissions measurement, integration, reporting and auditing that may provide significant potential risk for fraud to take place. The future research should direct the focus on a particular type of fraud and interviews based study on the actual motivations behind it.

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