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Environmental management accounting and its effects on carbon management and disclosure quality

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ABSTRACT

Along with the development of environmental management accounting (EMA) in the past decade, a variety of management accounting and control tools have been designed and implemented to improve the measurement and management of corporate environmental performance and information. While the importance of EMA to corporate sustainability has been increasingly acknowledged, extant literature has drawn little attention on assessing and understanding EMA application and its effectiveness on the quality of carbon emission management and disclosure. Using data gathered of 114 large firms in the US, Germany, Australia and Japan, we find that many firms have applied some EMA tools, yet only a few have applied the full range of EMA tools. The empirical analysis reveals that EMA application has a significantly positive impact on both corporate carbon management and disclosure quality. Further analysis specifies that audit and benchmarking tools as well as control tools have significant effects on carbon management and disclosure, while for measurement tools no significant effects could be observed. Based on the results, implications are developed for management education and practitioners, which can help managers to make better informed choices for the application of EMA tools.

1. Introduction

The annual Earth Overshoot Day marks the day on which human induced pollution exceeds the carrying capacity the earth provides for a given year. Constantly, this day is reached far before the end of the year and the overshoot increases each year (Posthuma et al., 2014; Worland, 2015). Carbon and other greenhouse gas emissions are one of the main drivers of this overshoot and large corporations are the main emitters of greenhouse gases, both historically, but also at present (CDP, 2013; Heede et al., 2014).

To measure environmental impacts including carbon emissions, environmental management accounting (EMA) has received growing attention for the past decades (e.g., Christ and Burritt, 2013; Ferreira et al., 2010; Gibson and Martin, 2004; Passetti et al., 2014; Schaltegger and Burritt, 2000) and a variety of EMA tools such as material flow cost accounting (Christ and Burritt, 2015; Strobel and Redmann, 2002), eco-control (Henri and Journeault, 2010) and the sustainability balanced scorecard (Hansen and Schaltegger, 2016), have been designed and increasingly implemented to reduce the environmental impacts of companies. While the focus of previous environmental and social accounting and reporting research is predominantly on environmental disclosure (Parker, 2005; Schaltegger et al., 2013), EMA has been increasingly used and investigated as a company-internal approach to support the quality of environmental management in corporate practice (Adams, 2002; Burritt et al., 2002). It has been acknowledged that EMA can play a significant role in spurring operational as well as organisational change towards reducing corporate environmental impacts (Bennett et al., 2003; Ferreira et al., 2010; Masanet-Llodra, 2006).

More recently, the usefulness of EMA has been explored and discussed in the context of corporate carbon management and accounting (Ascui, 2014; Burritt et al., 2011; Schaltegger and Csutora, 2012; Stechemesser and Günther, 2012). Governments around the world have attempted to drive corporate responses to climate change through the introduction of emission trading schemes and/or taxes, abatement and disclosure regulation that aim to reduce carbon emissions. Under the current European Emissions Trading Scheme (ETS), carbon pricing or other related carbon reduction mechanisms, it has become increasingly important for corporations to account for carbon emissions (Bell, 2017;

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Bowen and Wittneben, 2011; Engels, 2009; King, 2014; Qian and Schaltegger, 2017). The expectation that a first step towards reducing corporate carbon emissions is to improve transparency and disclosure of such emissions, has led to the establishment of initiatives such as the Carbon Disclosure Project (CDP). The CDP collects and publishes (voluntary) disclosure of the greenhouse gas emissions of the world's largest corporations.

While business managers may have learnt about the importance of EMA and applied this knowledge for carbon management or reporting, practical questions remain under-researched, e.g. which groups of EMA tools are useful to reduce carbon emissions effectively, and more specifically, whether the application of different EMA tools has an effect on corporate carbon management and disclosure. Despite insightful suggestions provided, previous EMA research is primarily either conceptual/descriptive, or focused on technical issues in EMA application through single or several case studies (e.g. in Ascui's 2014 review of carbon accounting development in social and environmental accounting literature, most of the 65 carbon accounting papers are conceptual with technical orientation on method development or representing case study experimentation). Different from reporting and other technical or more general sustainability management tools, such as life-cycle assessment and eco-efficiency analysis, that have been extensively studied in previous literature (Hellweg and Canals, 2014; Scipioni et al., 2010), EMA, as a package of useful accounting tools, has not been investigated in the context of carbon disclosure and management. Research has so far paid little attention to assessing the effectiveness of EMA application on the management and disclosure of corporate carbon emissions.

Against this background, this study focuses on the use of EMA as opposed to more general sustainability management tools, based on over two decades' evolvement of EMA tools. We empirically investigate the application of EMA in corporate practice and its influence on carbon management and disclosure quality. The investigation uses data collected for a larger project – the Corporate Sustainability Barometer (CSB) (Schaltegger et al., 2014) and analyses EMA application in 114 large companies across four developed nations, namely the U.S., Germany, Australia and Japan. The data collected in the CSB survey is examined against the carbon performance management and disclosure information provided by the Carbon Disclosure Project (CDP) database.

The contributions of this study are twofold. First, this paper extends the existing research by filling the gap in the literature where empirical investigations of the role of EMA in combatting climate change at the corporate level and the application of EMA and its effectiveness on improving carbon management are still lacking. It thus makes a rare attempt to analyse the link between different EMA tools and carbon management and disclosure. Second, from a practitioner's perspective, the findings of this empirical examination will provide implications for business managers to understand the usefulness of different EMA tools for corporate carbon management. Clearly, there has been an increasing number of EMA tools available to business managers (e.g. Burritt et al., 2002; Burritt et al., 2011), but implementing a full coverage or the 'whole set' of EMA tools appears unrealistic in terms of time and resource availability. As such, it is expected that the results of this study will help managers make better choices of EMA tools and consequently map out better carbon management activities.

The remainder of the paper is structured as follows. Section 2 provides a review of the development of EMA and its multidimensional tools elaborated in prior literature. Following the review, Section 3 outlines possible links between the use of EMA tools and carbon performance and information disclosure. The research method used for this study is discussed in Section 4 and the findings of the study are presented in Section 5. Section 6 discusses the results as well as its research limitations and future research opportunities.

2. Review of EMA development and application

2.1. Development of EMA

Conventional accounting focuses predominantly on profitability and ignores other major business impacts such as climate change, the use of non-renewable resources or other environmental issues as well as societal issues in supply chains. The unconsidered negative environmental and social impacts have motivated researchers to criticize conventional accounting and made environmental management accounting (and more broadly social, environmental and sustainability accounting) rise to prominence in recent years (e.g. Schaltegger et al., 2013). Differentiating itself from conventional accounting, EMA highlights the importance of tracing, managing and reporting 'full', 'total' or 'true' costs and impacts of business activities that conventional accounting often overlooks (Bebbington et al., 2001; Bracci and Maran, 2013; Epstein, 1996; Ferreira, 2004; Herbohn, 2005; Jasch, 2009; USEPA, 1998). In essence, EMA helps organizations to capture both economic and ecological footprints and to examine the entire operation of their corporations including the supply chains as an activity with both economic and ecological impacts (Bartolomeo et al., 2000; Bennett et al., 2002; UNDSD, 2001). To achieve this ultimate goal, business has to employ an environmental management system, including EMA, to record, analyse and report environmentally induced financial and ecological impacts of a defined economic system (e.g., a firm, plant, region, nation) (Burritt et al., 2002; Jasch, 2009; Schaltegger and Burritt, 2000). EMA has been increasingly seen as one of the master keys to unlock the perceived long standing tension between economic development and environmental degradation and to achieve "win-win" business cases (e.g. De Beer and Friend, 2006; Ferreira et al., 2010; Jasch, 2009; von Weizsäcker et al., 2009).

EMA is a broad-based term that encompasses various kinds of accounting and performance control tools (Bouten and Hoozée, 2013; USEPA, 1998). Rikhardsson et al. (2005) consider EMA a form of managerial technology encompassing various tools and techniques of targeted information collection, analysis and communication. This relatively new set of management accounting tools includes a variety of tools such as environmental cost accounting, material flow cost accounting (e.g. Christ and Burritt, 2015; Günther et al., 2015; Strobel and Redmann, 2002), benchmarking, auditing (e.g. Earnhart and Leonard, 2016), eco-control or balanced scorecards (e.g. Hansen and Schaltegger, 2016; Henri and Journeault, 2010), all aiming at helping companies seek improvement of their environmental, social and economic performances (Burritt et al., 2009).

2.2. Categories of EMA tools

Previous literature has explored this flexible and broad-based concept and suggested a number of characteristics and functions EMA can fulfil. These functions are summarized below in the three categories of (1) measurement, (2) auditing & benchmarking, and (3) control tools.

2.2.1. Measurement tools

The first and foremost characteristic of EMA is its emphasis on measuring *monetary and physical flows* in a life-cycle of a product or system. Previous studies indicate that conventional accounting uses predominantly monetary measures and places less weight on non-monetary information (Burritt et al., 2002; Gray and Bebbington, 2001). Environmental aspects of performance that involve non-monetary information may be completely ignored in conventional accounting (Bennett and James, 1997). EMA includes physical procedures for material and energy consumption, flows and final disposal, and monetary procedures for costs, savings and revenues related to the activities or material flows with a potential environmental impact (Burritt et al., 2002; UNDSD, 2001; IFAC, 2005). With its emphasis on linking monetary and physical measures, *material flow cost accounting* is one of the most prominent EMA methods (Günther et al., 2015; Jasch, 2009; Schaltegger and Zvezdov, 2015; Schmidt et al., 2015; Strobel and Redmann, 2002).

More generally, *environmental cost accounting* (or environmental costing) which requires separate identification, tracking and allocation of environmental costs and makes these costs more visible to managers, has been encouraged by many previous studies for business as well as not-for-profit organizations or cities (c.f. Benvenga et al., 2016; Burritt, 2000; Epstein, 1996; Hansen and Mowen, 2005; Henri et al., 2014; Giracol et al., 2011; Joshi et al., 2001; Parker, 2000; Passarini et al., 2014). It is claimed that visible costs captured in conventional accounting only account for a small portion of a firm's total environmental costs (Epstein, 1996). Specifically Joshi et al. (2001) empirically found that for every $1 increase in visible costs, there is around $10 increase in associated hidden costs, such as costs that could be avoided by taking environmental measures. This does not include the potentially much larger proportion of full or life cycle costs emphasised in full environmental cost accounting (Epstein, 1996). In a systems view, life-cycle analysis sets up product or service life-cycle inventories which enable to capture all possible environmental impacts cross an entire supply chain (Scipioni et al., 2010; Manzardo et al., 2016).

Furthermore, decisions on investment in environmental resources, assets or projects need support from eco-investment measures. *Eco-investment accounting* (or environmental investment appraisal) constitutes another important measurement approach of EMA. In appraising environmental investment alternatives, environmental costs such as water and electricity consumption, and return such as selling of recycled materials, need to be included and compared to assess the full costs and risks of different real investment alternatives (Bouten and Hoozée, 2013; Parker, 2000). When investigating the case of a rice mill, Burritt et al. (2009), for example, find that using EMA tools, particularly monetary and physical environmental investment appraisal, to assess environmental risks associated with dumping and burning of rice husk, helps to visualise the costs and benefits of two competing investment options. Eco investment accounting is also found to improve the long term environmental performance during the investment period.

Expanded from measuring and accounting for environmental performance, *sustainability accounting* emphasizes the integration of economic, environmental and social information. Although sustainability accounting is sometimes viewed by critical theorists as a management fashion or fad, from the management point of view, sustainability accounting can be used as an important tool to help set out short-term and long-term plans, identify resource constraints and utilise capacity for integrating and achieving financial, environmental and social responsibility (Burritt and Schaltegger, 2010). This tool has also been proposed in the context of carbon management accounting (Burritt et al., 2011).

2.2.2. Auditing and benchmarking tools

In addition to measurement, audit and benchmarking constitute another important element of EMA. Making comparisons and benchmarking against standards, guidelines and competitor performance are critical for ensuring environmental compliance and meeting environmental targets. *Eco-audit* (or environmental audit) involves systematic, documented (and usually regular) inspection procedures on ecological impacts of an organization. These procedures focus not only on conformity assessment, allowing a comparison of actual figures with internal targets or external standards/rules, but also on progress evaluation, helping organizations to improve processes, products and services (Earnhart and Leonard, 2016). *Sustainability audit* uses an even broader perspective, as the inspection procedures include the three dimensions of sustainability: social, ecological and economic. This process measures value and subsequent progress in the three dimensions. In particular, the values are measured through performance metrics against a set of performance indices (or criteria) or against a set of sustainability guidelines (Coyne, 2006). In line with auditing, eco- and sustainability *benchmarking* focus on the continuous comparison of environmental performance with other enterprises or corporate sectors in order to reveal a company's own strengths and weaknesses. This tool provides a way in which corporations can be held to account in terms of their environmental and social responsibility, providing a measure that has become a driver for many companies (Springett, 2003).

2.2.3. Control tools

Another important aspect of EMA is its environmental control function. EMA requires a proper management control system in place to ensure that the organization works on a daily basis to implement its intended strategy and integrate environmental factors into its core business. *Eco- and sustainability control* as a broad approach emphasizes the use of financial as well as strategic control methods to enable and facilitate the implementation of environmental strategy (Gond et al., 2012; Henri and Journeault, 2010; Schaltegger, 2011). The process of eco-control ensures that necessary financial and environmental information is appropriately captured and relevant resources are obtained in the accomplishment of corporate environmental objectives. More specifically, as a monitoring tool, eco-control represents an instrument of communication between managers and subordinates to share EMA information captured and make sound decisions for environmental improvement (Gond et al., 2012; Henri and Journeault, 2010). An *environmental information system* requires business corporations to systematically collect, process, and store information for environmental decision-making and is another essential EMA tool. An environmental information system complements a company's existing information systems by collecting and analyzing new types of information for the purpose of better planning, development, steering and control for environmental management (Pondeville et al., 2013). The establishment of a proper environmental information system may allow for the quantification of both economic and environmental value changes and the integration of environmental concerns within business routines.

Clearly, performance control for sustainability encompasses not only economic and environmental but also social performance evaluation and beyond. The *sustainability balanced scorecard* entails a systematic approach to linking sustainability management to business strategy (Figge et al., 2002; Hansen and Schaltegger, 2016). More precisely, sustainability balanced scorecards integrate environmental as well as social perspectives into the management and measurement process for corporate financial success, customer satisfaction, process improvement, organisational learning and product innovation (Figge et al., 2002). As such, it is a much discussed EMA tool for achieving corporate sustainability objectives. Most recently, Maas et al. (2016) emphasize the importance of linkages and the interplay between different EMA approaches to increase the effectiveness of environmental and sustainability management.

3. Hypothesis development

As reviewed in the previous section, the popularity of EMA in contemporary environmental and sustainability management is perhaps due to the close linkage between the two concepts. EMA can influence environmental management performance as it helps tracking and integrating monetary and physical environmental information, which increases the visibility of this information and associated environmental management activities to managers and employees. Consequently, companies applying EMA tools are more likely to search for better solutions to improve environmental management quality and performance.

The practice of using EMA tools to assist in environmental management decisions and to generate various environmental benefits has been elaborated in many previous studies and cases. Specific demonstrations include supporting waste reduction, managing carbon emissions and supporting managers' long term decision-making, for example, the decision to adopt cleaner production technologies (Burritt et al., 2009, 2011; Henri and Journeault, 2010; Parker, 2000). Jasch (2003) presents a case study of a Swedish pulp and paper company showing that EMA tools involving material and process flow accounting enable the distinction and comparison between alternatives in environmental spending incurred for end of pipe disposal and preventative technologies and training. These EMA applications can raise environmental awareness of managers and help to overcome their ignorance of the magnitude of the operation cost. Gale (2006) examines EMA applications in the Canadian paper industry, a highly polluting and energy intensive industry, and divulges that the environmental costs made available by EMA are at least twice as high as generally considered by business managers, which reiterates the opportunities and usefulness of EMA in supporting informed decision-making. More recent empirical assessments of the roles of environmental costing and eco-control tools in manufacturing firms reconfirm the positive relationship between EMA applications and the improvement of environmental management quality and performance (Henri and Journeault, 2010; Henri et al., 2014).

Manifested in climate change measures, better quality of carbon management may involve higher levels of carbon governance, operation, emission reporting and engagement (Tang and Luo, 2014). This requires an integration of the climate change strategy into core business and following an integrated strategy, developing adequate environmental initiatives and actions (CDP, 2012a, b, c, d, e). The effectiveness of EMA application on carbon emission reduction has been documented either explicitly or implicitly in a few of carbon accounting studies. For example, Burritt et al.'s (2011) case studies in Germany reveal that EMA is useful to support carbon management decisions, which may subsequently improve carbon management quality. Tang and Luo's (2014) empirical investigation of Australian listed firms also suggests that better tracking and measuring of carbon information can help to improve carbon management quality and therefore to achieve better carbon mitigation. Based on these insights, we propose the first hypothesis as follows:

H1. The application of EMA tools positively influences corporate carbon management quality.

Management orientated EMA studies support the view that EMA assists managers and employees in communicating corporate performance and achievements internally (Burritt and Schaltegger, 2010; Henri and Journeault, 2010). The pressures for corporate environmental responsibility may initially stem from internal and external stakeholder demands for more environmental information (Cho and Patten, 2007). However, business managers who are convinced to establish constant collecting, communicating and reporting of environmental information to improve internal business transparency and accountability, can be expected to gain more insights into how environmental management functions in the organization (Burritt and Schaltegger, 2010). This is expected to not only improve the internal decision-making process but also external stakeholder communication and engagement.

The application of EMA tools is likely to enhance corporate reputation by reducing environmental-related reputation costs which are increasing rapidly in the new sustainability and low carbon era for corporations emitting large amounts of greenhouse gases. While firms with 'good news' on their environmental management and carbon performance may have greater incentives to communicate with stakeholders (Bewley and Li, 2000; Clarkson et al., 2011; Li et al., 1997), stakeholder dialogue and disclosure help companies themselves to understand performance improvement and how to better signal it to stakeholders (Branco and Rodrigues, 2006; Rogers, 2008; Walden and Stagliano, 2003). Empirical studies have found significant associations between environmental management activities and the level of corporate environmental disclosure (e.g. Frost and Seamer, 2002; Lober et al., 1997; Patten, 2000) suggesting that environmental disclosure derives from information generated by underlying internal management practices. In this regard, it is logical to argue that higher corporate commitments to EMA will lead to more thorough understanding of internal and external carbon information needs. Therefore companies with high levels of application of EMA tools are more likely to achieve a more thorough and comprehensive carbon disclosure quality. Thus, the second hypothesis is:

H2. The application of EMA tools positively influences corporate carbon disclosure quality.

In practice, it is unlikely that each group of EMA tools shows the same effects. As described in Section two, each group of EMA tools follows a specific purpose. Literature on measurement tools in EMA highlights the ability of these tools to measure physical and monetary flows. Therefore, measurement tools can help to reveal hidden aspects of material or energy flows as well as the costs associated with these flows (e.g. Epstein, 1996; Jasch, 2009; Schaltegger, 1998; Strobel and Redmann, 2002). This enables managers to identify which specific processes cause the environmental damages related to a firm's activities. Jasch (2003, 2009) and Burritt et al. (2009) for example demonstrate how the use of measurement tools can help to identify the environmental impacts and costs associated with different investment alternatives. The application of these tools thus allows managers to choose alternatives that are less environmentally harmful. Transferring these earlier insights to the context of corporate carbon management, it can be expected that measurement tools are primarily useful to identify potentials for reducing environmental burdens and thus to improve carbon management.

Likewise, control tools can assist companies in implementing their environmental strategies. They help to identify whether some aspects of these strategies do not work as intended or whether some of the environmentally relevant aims are not met (Gond et al., 2012; Henri and Journeault, 2010; Schaltegger, 2011). This can help companies to take countermeasures and thus to improve their environmental performance. Henri and Journeault (2010) show that eco-control effectively helps with implementing an environmental strategy, as companies applying such tools show lower levels of environmental pollution. Similarly, Hansen and Schaltegger (2016) highlight the potential of one specific control tool, the sustainability balanced scorecard, to improve environmental performance of different types of organizations. At a more general level, Lisi (2015) finds that company internal control measures help companies to improve their environmental performance. Based on the previous investigations on the effects of the application of control tools in various contexts of environmental management, it can be expected that control tools are able to improve corporate carbon management quality.

In contrast, audit and benchmarking tools measure a company's performance against the performance of competitors, external standards or along the lines of externally given audit criteria (Coyne, 2006). In the context of corporate carbon management, these tools require collecting carbon emissions data in a standardized format that allows comparisons and benchmarking with competitors or externally provided standards (Springett, 2003). This can motivate companies to make their achievements visible to others, helping companies to realistically assess their own achievements and take their environmental responsibility (Springett, 2003). These functions of audit and benchmarking tools highlight that such tools focus on comparing the final result of environmental management activities with externally given values and goals, instead of focussing on influencing the final result of environmental management activities. Thus, it can be expected that the main benefit of the application of benchmarking and audit tools is to improve corporate environmental disclosure (Springett, 2003). Earlier examinations in the general field of environmental management support this expectation. Lyon and Maxwell (2011) for example demonstrate that auditing can contribute to improvements of corporate environmental disclosure. Similarly, Bewley and Li (2000) suggest that disclosure can be improved if high quality audits are conducted. Applying these insights to the context of carbon management, it can be expected that the application of audit and benchmarking tools positively influences carbon disclosure quality.

Based on the above considerations, we propose the following hypotheses on the specific effects of different groups of EMA tools on carbon management quality and carbon disclosure quality:

H3a. The application of measurement tools positively influences carbon management quality.

H3b. The application of control tools positively influences carbon management quality.

H3c. The application of audit and benchmarking tools positively influences carbon disclosure quality.

4. Research method

4.1. Data collection

The data used for the statistical analysis builds on two different sources, the Corporate Sustainability Barometer (CSB) (Schaltegger et al., 2014), a survey of large multinational companies, and the Carbon Disclosure Project (CDP). The data on EMA tool application was collected from the CSB survey carried out in 2012. CSB is a project investigating sustainability management practices, including EMA practices, of the largest companies in eleven industrialised countries. For this paper, survey data from four countries, Australia, Germany, Japan and the USA, were used because of sufficient carbon management data available in the CDP database for these countries. Of the 1045 firms surveyed in these four countries, 282 responded to our questionnaires, which resulted in a response rate of 27%.

The survey participants were mainly corporate sustainability managers (or equivalent) as they were considered to have a good overview of their companies' sustainability management activities and relevant tools employed. The sustainability managers were first contacted by e-mail or phone and then provided with an online survey questionnaire. In this questionnaire, a list of EMA tools was provided and the respondents were asked to indicate which tools their companies apply. The list of EMA tools is detailed in Table 2. The survey questions relevant for this research are provided in Appendix A.

The data on carbon measurement and management is collected from the database of CDP, an international organization collecting and disclosing information related to corporate actions on climate change. The CDP has created the largest registry of corporate greenhouse gas emission data for the world's largest publically listed corporations. Despite the voluntary and self-reported nature of corporate carbon information, the data can be regarded reliable, as corporate survey responses to the CDP are under close public scrutiny and observed by sustainability rating agencies. The CDP has engaged with hundreds of large institutional investors globally to urge corporations to provide their carbon management and emission information (CDP, 2013). Using different data sources for the variables of this study helps avoid a common method bias and thereby increases the robustness of the examination (Podsakoff et al., 2003).

To match the survey data, we used 2012 CDP reporting data for the four countries investigated. More specifically, data were sourced from the CDP Global 500 climate change report 2012 (CDP, 2012a); Australia and New Zealand (ASX200 & NZX50) climate change report 2012 (CDP, 2012b), S&P 500 climate change report (CDP, 2012c), Germany, Austria, Switzerland 350 climate change report 2012 (CDP, 2012d), and Japan 500 climate change report (CDP, 2012e). However, matching the CSB data with the CDP data revealed that only 114 of the 282 firms responding to the CSB survey data were available in the CDP dataset. Therefore, these 114 firms constitute our final sample. The descriptive statistics of the final sample are displayed in Table 1.

While Germany has the highest number of participating companies (N = 42; 37.9%) the sample in Australia is the smallest (N = 18; 15.8%). This partially reflects the different sizes of the two economies. The revenue of the sample companies range from over €50 million to over €50,000 million per year. Nearly half of the sample firms (N = 53; 46.5%) have the revenue within the range of €5000 million to €50,000 million. The sample firms are dispersed in each of the four industry sectors, with 'Financials' having the highest number of participating firms. Overall, the sample firms are reasonably diverse in terms of country, size and industry affiliation.

4.2. Variable measurement

4.2.1. Independent variables

The independent variables in this study include a series of EMA tools. They are categorised into the three groups introduced in Section 2.2: measurement tools, audit & benchmarking tools, and control tools. Each tool group includes four EMA tools. A description of these tools is shown in Table 2.

Participating firms were asked to indicate whether they have applied the individual tools listed or not (1 = application; 0 = no application). The overall measure of EMA tool application was calculated as the sum of the EMA tools applied. The overall values for EMA tool application ranged from a minimum of 0 tools (no application) to a maximum of 12 tools (application of all selected tools) and for each tool group, the values ranged from 0 to 4 (as each group consists of four tools).

4.2.2. Dependent variables

The *carbon disclosure scores* in the CDP reflect the thoroughness

Table 1
Economic profiles of sample firms.

Variable	Category	N	%
Country	Australia	18	15.8%
	Germany	42	37.9%
responses	Japan	33	28.9%
	USA	21	18.4%
Revenue	More than €50 million and up to €500 million	7	6.1%
	More than €500 million and up to €1500 million	7	6.1%
	More than €1500 million and up to €2500 million	11	9.6%
	More than €2500 million and up to €5000 million	20	17.6%
	More than €5000 million and up to €50,000 million	53	46.5%
	More than €50,000 million	16	14.1%
Sectors	Financials (Finance & services)	36	31.6%
	Material & Engineering (Commodities, auxiliary material, energy, chemical & pharmaceutical industry)	35	30.7%
	Industrials (Industry, capital goods, building)	27	23.7%
	Consumer (Consumer goods, trade, logistics)	16	14.0%

of information reporting in each participating company (CDP, 2013). According to CDP, the quality of carbon disclosure is based on the comprehensiveness of reporting on general risks and opportunities of climate change, the impact of existing and future carbon emission regulations, the physical risk of climate change, innovations developed in response to climate change, the responsible management group or personnel for climate change, quantitative emission levels, emissions associated with products, services and supply chains, emission reduction strategy and investment, strategies for emission trading, and energy consumption and costs. The CDP disclosure scores range from 0 (no disclosure) to 100 (full disclosure).

Carbon management quality in this study is measured by a performance range (called "band") assessed in the CDP database. Companies are ranked from A (leaders) to E (laggards) according to CDP (2012a) criteria as follows: Band A (or A-) firms have a fully integrated climate change strategy driving significant maturity in climate change initiatives and actions; band B firms are characterized by recognizing climate change as a priority in their corporate strategy, but not all initiatives have been fully established; band C firms have some activity to combat climate change with varied levels of strategy integration of those initiatives; band D firms only provide limited information on their mitigation or adaptation initiatives and on their strategy concerning climate change; and band E firms show little evidence of carbon management initiatives and activities, potentially due to just beginning to take action on climate change. Based on this grouping, we coded sample firms from "5" – highest quality of carbon management to "1" – lowest quality of carbon management. Additionally to the firms assessed as laggards by the CDP (band E), we also included firms with carbon disclosure scores below 50 in category 1, as the CDP suggests that such firms show little involvement and management of carbon emissions (CDP, 2013).

4.2.3. Control variables

Companies can be expected to be less incentivized to develop (particularly advanced) EMA tools and use them to improve their environmental management and disclosure quality, if they are characterized by smaller capitalization, lower environmental/carbon sensitivity and lower financial capability/resources (e.g. lower

Table 2
Description of EMA tools.

Group of tools	Individual tools	Description	Literature (examples)
Measurement tools	Material flow cost accounting	Identify and analyse flows (input and output) of materials and energy in a production process or a service system in order to discover reduction potentials.	Strobel and Redmann (2002), Jasch (2009), Günther et al. (2015), Christ and Burritt (2015)
	Environmental cost accounting	Identify, track and allocate full life cycle costs, including costs that are caused by environmental protection measures or by the lack of environmental protection measures, and the costs that could be avoided by taking environmental measures.	Epstein (1996), Bebbington et al. (2001)
	Eco-investment accounting (environmental appraisal)	Assess the environmental benefits and costs of planned investment alternatives in order to support selection decisions.	Parker (2000), Burritt et al. (2009)
	Sustainability accounting	A set of tools used to identify and integrate economic, social and environmental information to provide help for managers dealing with business sustainability decisions.	Burritt and Schaltegger (2010)
Audit & benchmarking tools	Eco-Audit (environmental audit)	Systematic, documented (and usually regular) inspection procedures on ecological aspects, which allow a comparison of actual figures with internal targets or external standards/rules.	Earnhart and Leonard (2016)
	Sustainability Audit	Systematic, documented (and usually regular) inspection procedures on sustainability aspects. They allow a comparison of actual figures with a set of sustainability guidelines.	Coyne (2006)
	Eco-benchmarking	The continuous comparison of environmental performance with other enterprises or corporate sectors in order to reveal a company's own strengths and weaknesses.	Springett (2003)
	Sustainability benchmarking	The continuous comparison of social, environmental and economic performance with other enterprises or corporate sectors in order to reveal a company's own strengths and weaknesses.	Schaltegger et al. (2014)
Control tools	Eco-control	The use of financial as well as strategic control methods to enable and facilitate the implementation of environmental strategy and achieving environmental performance objectives.	Henri and Journeault (2010); Journeault et al. (2016)
	Environmental information system	Systematic analysis of data on corporate environmental impacts for the purpose of better planning, development, steering and control for environmental management.	Pondeville et al. (2013)
	Sustainability balanced scorecard	Integrate environmental and social aspects into conventional Balanced Scorecard performance measures in order to allow strategic management for sustainability performance.	Figge et al. (2002); Hansen and Schaltegger (2016)
	Sustainability control	The use of financial, social and environmental control methods to enable and facilitate the implementation of corporate sustainability strategy and achieving sustainability performance objectives.	Gond et al. (2012); Schaltegger (2011)

profitability and sales growth). These contextual noises are therefore likely to change the effect and effectiveness of the use of EMA tools on carbon management and disclosure quality. For example, larger companies may have higher media exposure and thereby incur higher political costs (Gamerschlag et al., 2010). Therefore, they are likely to better manage and disclose their carbon emissions (Brammer and Pavelin, 2006; Deegan and Gordon, 1996). In this study, firm size (*Size*) was measured by the natural logarithm of the companies' total sales revenue, as surveyed in the CSB project.

Likewise, firms with higher financial performance may be more likely to invest in environmental activities which will lead to higher quality of management and disclosure (Deegan and Gordon, 1996; King and Lenox, 2001). Lang and Lundholm's (2000) study provide evidence of a positive relationship between earnings and environmental disclosures. Consistent with prior studies, financial performance was measured by the companies' annual return on assets (*ROA*) indicated in company financial reports.

Industry affiliation may influence a firm's environmental/carbon sensitivity which has been found to be an important factor influencing environmental management and disclosure (e.g. Frost and Wilmshurst, 2000; Cho and Patten, 2007). Table 1 shows a relatively equal coverage of four industry sectors within our sample. Therefore, we used an industry dummy to control the influence of individual industries, as outlined in Table 1. The industry dummy was gained based on CSB survey data, where companies stated their core business activities. According to these statements, industry affiliation was coded by at least two independent coders. Similarly, as this study contains data from four different countries, we created 4 country dummies to control the effects of countries of which one (Japan) was used as reference category.

5. Results analysis

5.1. Descriptive results

The descriptive statistics of variables are displayed in Table 3. The results show that within a range of 1–5, the median carbon management quality level of the sample firms is 3. This indicates a moderate level of carbon management quality. The average (median) carbon disclosure scores are 73.13 (76.00), which can again be considered as a moderate level (if any score below 50 is considered as poor disclosure and any score above 90 as excellent quality disclosure). The mean (median) value of total EMA application is 3.58 (2.00). Given the range of this variable is between 0 (no application) and 12 (full application), the average EMA use among sample firms is relatively low. The lowest application is found among measurement tools (average of 0.78 in a range between 0 and 4).

A further analysis of the application of individual EMA tools by the sample firms shows that more than half of the sample firms (54.4%) have not applied any measurement oriented tools. Within the 45.6% firms that have applied measurement tools, half of them applied only one tool. There is one company (<1%) that has applied all four measurement tools. The application of audit and control tools presents more diverse characteristics. Over 77% of all firms applied one audit and benchmarking tool or more, the highest application among the three groups of EMA application. Although the majority of companies have still applied just one or two tools, 12.3% of the companies have applied all four selected audit and benchmarking tools. About 64% of companies have applied control tools but half of them have only applied one of the control tools. 5.3% of the companies have applied all control tools. Table 4 presents the correlation between variables.

The correlation table indicates a high association between carbon management and disclosure quality. The connections between individual groups of EMA tools are moderately correlated while the correlations between independent and control variables are all relatively low, showing little sign of multicollinearity. This is confirmed in the regression analysis where we tested variance inflation factor (VIF) for each variable and the mean VIF for each model is less than 1.7 (a VIF value greater than 10 may indicate a multicollinearity problem (Kennedy, 1992)).

5.2. Hypothesis testing

Table 5 reports the effect of EMA application on carbon management and disclosure quality. As carbon management quality is measured as an ordinal variable, *Ordered Logistic Regression* (OLR) is used to examine this dependent variable. Carbon disclosure quality is measured as a continuous variable and thus the *Ordinary Least*

Table 3
Descriptive statistics.

Variable	Mean	Median	Std. Dev.	No. of tools applied	No. of firms	%
Carbon management quality	–	3.00	1.25			
Carbon disclosure quality	73.13	76.00	17.78			
Size	8.97	8.88	1.55			
ROA	3.66	3.33	10.26			
Total EMA application	3.58	2.00	2.92			
Measurement tools	0.78	0.00	1.03	None applied	62	54.4
				One or more tools applied	52	45.6
				• 1 tool applied	26	22.8
				• 2 tools applied	15	13.2
				• 3 tools applied	10	8.8
				• 4 tools applied	1	0.9
Audit & benchmarking tools	1.61	1.00	1.32	None applied	26	22.8
				One or more tools applied	88	77.2
				• 1 tool applied	36	31.6
				• 2 tools applied	21	18.4
				• 3 tools applied	17	14.9
				• 4 tools applied	14	12.3
Control tools	1.19	1.00	1.21	None applied	41	36.0
				One or more tools applied	73	64.0
				• 1 tool applied	36	31.6
				• 2 tools applied	16	14.0
				• 3 tools applied	15	13.2
				• 4 tools applied	6	5.3

Table 4
Spearman correlation between tested variables.

	Carbon mgmt.	Carbon discl.	EMA tools	Meas. tools	Audit & ben. tools	Control tools	Size	ROA
Carbon management quality	1.00							
Carbon disclosure quality	**0.86**	1.00						
EMA application	**0.37**	**0.34**	1.00					
Measurement tools application	0.13	0.15	**0.70**	1.00				
Audit and benchmarking tools application	**0.36**	**0.34**	**0.85**	**0.42**	1.00			
Control tools application	**0.37**	**0.33**	**0.81**	**0.43**	**0.57**	1.00		
Size	**0.52**	**0.50**	0.13	−0.03	0.17	0.18	1.00	
ROA	0.04	0.01	0.06	0.14	0.05	−0.01	−0.03	1.00

Significant coefficients ($p < 0.05$) for EMA application are highlighted in bold.

Table 5
The effect of EMA tools on carbon management and disclosure quality.

Variables	1. Carbon management quality model			2. Carbon disclosure quality model		
	Coef.	z	*P*	Coef.	t	*P*
EMA application	**.24**	3.33	.00	**1.46**	3.01	.00
Size	.78	5.45	.00	5.36	6.23	.00
ROA	.04	1.54	.12	.50	3.72	.00
Germany	−.09	−.20	.85	−.19	−.06	.95
Australia	.64	1.14	.26	.49	.12	.91
USA	.41	.71	.48	.00	.00	.99
Industrials	−1.43	−2.37	.02	−11.27	−2.58	.01
Financials	−.23	−.39	.69	−5.58	−1.33	.19
Mat&Eng	−.28	−.50	.62	−5.94	−1.40	.16
Intercept				24.18	2.78	.01
LR chi^2	68.92(.00)					
Pseudo R^2	.19					
F				9.64(.00)		
Adj R^2				.41		

Unstandardized regression coefficients are reported. Significant coefficients ($p < 0.05$) for EMA application are highlighted in bold.

Squares (OLS) regression is applied for the second model. For the country variable, Japan has been specified as the reference category. For industry affiliation, 'Consumer' serves as the reference category.

The results show that the application of EMA tools has a significant and positive effect (*Coef.* = 0.24; *p* = 0.00) on carbon management quality. Consequently, hypothesis 1 can be supported. Similarly, the application of EMA tools has a significant, positive influence (*Coef.* = 1.46; *p* = 0.00) on carbon disclosure quality. Hypothesis 2 is therefore supported too. Firm size is a significant contributor to both carbon management (*Coef.* = 0.78; *p* = 0.00) and disclosure quality (*Coef.* = 5.36; *p* = 0.00), suggesting that larger firms are more likely to ensure higher carbon management quality as well as disclosure quality. ROA only has a significant effect on carbon disclosure quality (*Coef.* = 0.50; *p* = 0.00) but not on management quality (*Coef.* = 0.04; *p* = 0.12). The country and industry factors do not show any particular effect in the models, except that the 'Industries' sector reports a significantly negative effect on carbon management (*Coef.* = −1.43; *p* = 0.02) and disclosure quality (*Coef.* = −11.27; *p* = 0.01), i.e. firms in the 'industries' sector are more likely to have lower carbon management and disclosure quality compared to the reference sector – 'Consumer'. Table 6 displays the effects of the application of the individual groups of EMA tools on carbon management quality (Model 1 – OLR regression) and disclosure quality (Model 2 – OLS regression).

In the third set of hypotheses, it is expected that the application of measurement tools as well as of control tools positively influences carbon management quality (H3a; H3b), while the application of audit and benchmarking tools positively influences carbon disclosure quality (H3c). The results in Table 6 report that audit tools and control tools have a significant effect on carbon management and disclosure quality improvement ($p \leq 0.01$ as highlighted in bold). For measurement tools, no significant effect could be observed. Therefore, hypotheses 3b and 3c are confirmed, but hypothesis 3a is rejected. Besides the hypothesized effects, control tools were additionally found to positively influence carbon disclosure quality and audit tools were additionally found to positively influence carbon management quality. All models in Table 6 are significant at below 0.01 levels. The Pseudo R squares in the OLR models for carbon management quality range from 0.17 to 0.19 and the adjusted R squares in the OLS models for carbon disclosure quality are between 0.37 and 0.41.

Table 6
Effects of different groups of EMA tools on carbon management and disclosure quality.

Variables	Measurement Tools	Audit Tools	Control Tools
Model 1: The effects on carbon management quality			
Measurement tools	.34(.07)		
Audit & benchmarking tools		**.43 (.00)**	
Control tools			**.56(.00)**
Size	.80(.00)	.77(.00)	.77(.00)
ROA	.03(.16)	.03(.24)	.04(.10)
Germany	.20(.65)	.00(.99)	−.18(.69)
Australia	.79(.16)	.75(.18)	.32(.57)
USA	.93(.09)	.75(.18)	.19(.76)
Industrials	−1.33(.03)	−1.23(.04)	−1.46(.02)
Financials	−.23(.69)	−.11(.85)	−.35(.55)
Mat&Eng	−.18(.75)	.00(.99)	−.23(.68)
LR chi^2	60.79(.00)	66.20(.00)	67.66(.00)
Pseudo R^2	.17	.19	.19
Model 2: The effects on carbon disclosure quality			
Measurement tools	2.09(.13)		
Audit & benchmarking tools		**2.67 (.01)**	
Control tools			**3.76(.00)**
Size	5.78(.00)	5.22(.00)	5.28(.00)
ROA	.48(.00)	.45(.00)	.53(.00)
Germany	1.55(.64)	.44(.90)	−.82(.81)
Australia	1.64(.70)	1.29(.76)	−1.54(.72)
USA	2.94(.48)	2.23(.59)	−1.79(.68)
Industrials	−11.24(.01)	−10.38(.02)	−11.70(.01)
Financials	−5.82(.18)	−5.21(.22)	−6.39(.13)
Mat&Eng	−5.31(.23)	−4.35(.31)	−6.21(.15)
Intercept	22.63(.01)	25.00(.01)	26.91(.00)
F	8.38(.00)	9.16(.00)	9.73(.00)
Adj R^2	.37	.39	.41

Unstandardized regression coefficients are reported. The level of significance is given in brackets. Significant coefficients ($p < 0.05$) for EMA tools are highlighted in bold.

5.3. Sensitivity analysis

As some EMA tools may contain substitutable elements (e.g.

environmental cost accounting and material flow cost accounting may have some elements in common; some possible substitutive nature embedded in sustainability balanced scorecard and sustainability control), we conducted a sensitivity analysis, to ensure the robustness of our tests and analysis. Firms were assigned “1” if they indicated the use of one or more of the tools in a particular tool group, and “0” if none of the listed tools was applied. In this alternative measurement, firms applying more than one tool in a group were not differentiated from companies applying only 1 tool, so as to minimise the effect of interpretation bias on their answers. As the overall measure of EMA tools was based on the addition of the value in each tool category (the assigned value in each tool category was either 0 or 1), the overall value of EMA tools ranged from 0 to 4. The results from the alternative measures are presented in Appendices B and C. Both appendices show that the results are consistent with the findings in Tables 5 and 6 Thus, EMA application is consistently found to be a positive contributor to carbon management and disclosure quality. Again, control and audit tools have significant effects, whereas measurement tools show no significant effects on carbon management and disclosure quality.

6. Discussion and conclusion

While the importance of using EMA tools has been increasingly acknowledged in extant literature (e.g. Ascui, 2014; Bennett et al., 2003; Burritt and Saka, 2006; Ferreira et al., 2010), little attention has been paid on assessing and understanding the application of different EMA tools and their effectiveness on carbon management and disclosure. Using data gathered with the Corporate Sustainability Barometer survey of large companies in Germany, Australia, Japan and the USA, and data on the carbon performance and disclosure collected from the CDP database, this study finds a relatively low level of application of EMA tools. While this may reflect uncertainty among managers concerning the effectiveness of EMA, our study shows that the use of EMA tools is positively and significantly associated with carbon management and disclosure quality.

With regard to the challenge outlined in the introduction, i.e. staying within the carrying capacity of the earth, the findings show that EMA tools are effective in managing carbon emissions. They are useful for managers to address the challenge of climate change and to become more aware of carbon emissions. These results complement several prior studies on the effects of other groups of management tools (e.g. sustainability management tools, product design tools; see Hörisch et al., 2015a), or of some individual tools (e.g. eco-control or company internal emission trading schemes (Henri and Journeault, 2010; Hörisch, 2013), on corporate carbon performance. In this regard, a further challenge for practitioners is to decide which tools to use and which EMA tools are most effective.

With regard to this challenge, we analysed three separate groups of EMA tools (measurement tools, audit & benchmarking tools, and control tools) and their effectiveness on carbon management and disclosure quality. Our results highlight that while audit and control oriented tools have a significant positive impact on carbon management and disclosure quality, the effect of measurement tools analysed is not found to be significant. Given this insight, it might not surprise that the number of firms applying measurement oriented tools is lower than those applying the other two groups of EMA tools (i.e. control tools; audit & benchmarking tools). This result should encourage practitioners to apply audit and control tools to improve their carbon management and disclosure while at the same time it calls for more research on developing new and more effective measurement tools to support carbon management and disclosure.

Previous research documents that knowledge of sustainability management tools is a key driver of their application (Hörisch et al., 2015a; Schaltegger et al., 2012). A possible explanation for the lower level of application of measurement tools might thus be a lower level of awareness of these tools among managers. Managers might be more familiar with audit and benchmarking tools than with measurement tools, as they are relatively simple to apply. Therefore, audit and benchmarking tools are currently more likely to be applied. Auditing tools are also more related to external communication than measurement tools (Maas et al., 2016; Prajogo et al., 2016; Springett, 2003). Measurement tools often require the establishment of more sophisticated continuously operating information management systems. For carbon audit and benchmarking, information needs to be processed for internal and external auditors. This may build a useful first step in processing information and establishing a continuously operating, institutionalized measurement and accounting system, and certification practice (Prajogo et al., 2016). Therefore, audit and benchmarking are likely to be perceived useful in the short term and chosen by business managers to support the reporting process. In addition, audit and benchmarking tools have a longer history than measurement tools such as environmental full cost accounting and material flow cost accounting. As a consequence managers and employees are more likely to be acquainted with audit and control tools than the relatively younger measurement tools. Control tools extend and integrate the work of audit, benchmarking and measurement and link them to strategic uses. This may explain why control tools significantly influence carbon management quality. The effectiveness of audit and control tools on carbon management improvement is determined not only by the extent to which a company engages with these tools, but also by the comprehensiveness and quality of the application of these tools. An important interpretation of the positive results found in this study is that business managers and practitioners need to go beyond their current anecdotal application of audit and control tools. Instead, their ability to consolidate the knowledge and expand the application of these tools will significantly impact on their future success in carbon management and reporting.

The result that the application of measurement tools does not exert a significant impact on carbon management and disclosure quality echoes Frost and Seamer's (2002) earlier findings that disclosure is more associated with management and control tools than with accounting and reporting tools which may be strongly influenced by reporting standards and guidelines. The inference from current business practice is that external environmental reporting requirements may be too detached from business internal decision making processes. If what is measured will be what actually gets managed, the lack of solid application of measurement-orientated tools will compromise the effectiveness of audit and control tools on carbon management in the long run. In this regard, solutions to the alignment of external reporting requirements with internal measurement of environmental information should be actively sought by researchers and business practitioners.

Besides the insights our research offers, it also comes along with a few limitations. First, our analysis does not include all tools which are potentially relevant for corporate carbon management. While some tools have already been considered in earlier research, such as Life Cycle Assessment and Carbon Footprinting (e.g. Hörisch et al., 2015b), further tools not considered in this research, but relevant for future investigations on carbon management and disclosure are for example Greenhouse Gas Management Systems or Eco-Efficiency Analysis. With regard to the methodology, we acknowledge the limitation that the survey was conducted in 2012. Together with the matching CDP reporting data from the same year, any new development of EMA or improvement of carbon management and disclosure in the last couple of years may not have been captured in the results of this study. In addition, the carbon measurement and management information in the CDP database is voluntary and self-reported. However, CDP has consistently assessed corporate carbon management strategies and the quality of managing carbon information through its annual international survey. A further limitation might be that companies which participate in voluntary surveys and report to the CDP might be more likely to show above average commitment to the issue being surveyed. Future studies could investigate the effects of applying EMA tools specifically among companies identified as laggards. Furthermore, this research has focused on the quantity of EMA tools applied, in line with the quantitative research approach chosen. However, it is acknowledged that the quality and process of EMA implementation are of relevance to the development of carbon management and reporting. Future qualitative research should therefore investigate in how far qualitative differences with regard to EMA tool application influence carbon management and disclosure quality.

Additionally, future studies may be needed to further explore the differences of EMA tools, their effectiveness with regard to management quality, disclosure quality and in the reduction of carbon impacts. This would create more knowledge as to where and how to refine and improve measurement tools and how the interplay between different EMA tools (Maas et al., 2016) can be managed to better serve companies in combating climate change. Given the insights that EMA tools are generally effective in improving carbon management performance and disclosure, as well as the insight which tools are most effective, research is now challenged to identify what drives the application of these EMA tools. For the more general context of sustainability management tools, Hörisch et al. (2015b) found that creating knowledge about these tools among sustainability managers is a key driver of their application in large corporations as well as in small and medium sized enterprises. Therefore, public policy and universities should be encouraged to incorporate sustainability management and accounting into their current business curricula and executive education.

Further research could address which factors, besides knowledge, are important to stimulate the application of EMA tools which were found to be effective in this research. One possible reason for the differences in the application of EMA tools could for example be the different legal frameworks different companies in different industry sectors and different countries are subject to. Future research could investigate whether the application of EMA tools or their effectiveness is higher among companies subject to emission trading schemes or other pricing mechanisms for carbon emissions, such as carbon taxes. Furthermore, as climate change is by far not the only environmental problem which causes an overshoot, future research could investigate the effects of the EMA tools analysed on further aspects of environmental pollution and environmental management quality, such as biodiversity loss or the use of natural resources.

Appendix A. Survey questionnaire about the application of EMA tools (An excerpt from Corporate Sustainability Barometer survey)

- What was your company's revenue in the last financial year (in millions of dollars [unit of measurement depending on domestic currency)?
  (For banks and insurance companies: What was the balance sheet total or the gross premiums in millions of dollars of your company in the last financial year?)
  $ _______ million
- What is the core business of your company?
  (Please list the most important business activity/activities of your company.)
- Which methods of sustainability management are known in your company and which are applied in your company?

Please tick one box per line or none (if tool is neither known nor applied).

Control & Managing	Known	Known and applied
Environmental information system		
Eco-control		
Sustainability control		
Sustainability balanced scorecard		
Eco-audit		
Sustainability audit		
Other: ___________		
Measuring & Comparing	**Known**	**Known and applied**
Material flow cost accounting		
Environmental cost accounting		
Sustainability accounting		
Eco-benchmarking		
Sustainability benchmarking		
Eco-investment accounting		
Other: ___________		

Appendix B. The effect of EMA tools on carbon management and disclosure quality

Variables	1. Carbon management quality model			2. Carbon disclosure quality model		
	Coef.	z	*P*	Coef.	t	*P*
EMA application	.69	3.32	**.00**	4.79	3.43	**.00**
Size	.75	5.26	.00	5.06	5.87	.00
ROA	.04	1.62	.10	.52	3.95	.00
Germany	.09	.19	.85	.62	.19	.85
Australia	.69	1.21	.23	.56	.14	.89
USA	.58	1.04	.30	1.05	0.26	.80
Industrials	−1.35	−2.24	.03	−11.03	−2.56	.01
Financials	.01	.02	.99	−4.13	−.99	.33
Mat&Eng	−.15	−.27	.78	−5.58	−1.34	.18
Intercept				21.99	2.55	.01
LR chi^2	69.01(.00)					
Pseudo R^2	.19					
F				10.16(.00)		
Adj R^2				0.42		

Unstandardized regression coefficients are reported. Significant coefficients ($p < 0.05$) for EMA application are highlighted in bold.

Appendix C. Effects of different groups of EMA tools on carbon management and disclosure quality

Variables	Measurement Tools	Audit Tools	Control Tools
Panel A: The effects on carbon management quality			
Measurement tools application	.54(.14)		
Audit and benchmarking tools application		**1.47 (.00)**	
Control tools application			**1.08(.01)**
Size	.79(.00)	.76(.00)	.72(.00)
ROA	.03(.20)	.04(.15)	.04(.15)
Germany	.22(.61)	.27(.55)	−.04(.93)
Australia	.97(.10)	.97(.10)	.44(.43)
USA	.98(.07)	1.09(.05)	.52(.37)
Industrials	−1.28(.03)	−1.03(.09)	−1.37(.03)
Financials	−.22(.70)	.22(.71)	−.17(.77)
Mat&Eng	−.08(.89)	.14(.80)	−.02(.97)
LR chi^2	59.54(.00)	67.24(.00)	64.16(.00)
Pseudo R^2	.17	.19	.18
Panel B: The effects on carbon disclosure quality			
Measurement Tools	4.94(.07)		
Audit Tools		**9.25 (.01)**	
Control Tools			**7.78(.01)**
Size	5.73(.00)	5.14(.00)	4.99(.00)
ROA	.47(.00)	.50(.00)	.51(.00)
Germany	1.62(.63)	2.15(.51)	.33(.99)
Australia	1.13(.79)	2.59(.54)	−.91(.83)
USA	3.13(.45)	4.37(.28)	.34(.94)
Industrials	−11.07(.02)	−9.78(.03)	−11.52(.01)
Financials	−5.73(.19)	−3.54(.42)	−5.50(.20)
Mat&Eng	−5.09(.24)	−3.87(.36)	−5.06(.24)
_cons	22.38(.02)	20.67(.02)	27.62(.00)
F	8.56(.00)	9.39(.00)	9.17(.00)
Adj R^2	.38	.40	.39

Unstandardized regression coefficients are reported. The level of significance is given in brackets. Significant coefficients ($p < 0.05$) for EMA tools are highlighted in bold.

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