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Are Corporate Carbon Management Practices Reducing Corporate Carbon Emissions?

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ABSTRACT

This paper is the first large scale, quantitative study of the impact of corporate carbon management practices on corporate greenhouse gas (GHG) emissions. Using data for 2009 and 2010 from the Carbon Disclosure Project survey, we find little compelling evidence that commonly adopted management practices are reducing emissions. This finding is unexpected and we propose three possible explanations for it. First, it may be because corporate carbon data and management practice information have not been reported in a standardized way. Second, there may be a delay between the application of corporate carbon management practices and their impact on emissions performance. Third, carbon management practices are not sufficiently impact-oriented, meaning there is no relationship to observe. Our findings are important for policymakers designing corporate GHG reporting standards, for the multiple stakeholders trying to understand the drivers of corporate carbon performance, and for the corporate managers responsible for measuring, reporting and mitigating emissions. Copyright © 2015 The Authors. *Corporate Social Responsibility and Environmental Management* published by ERP Environment and John Wiley & Sons Ltd.

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Introduction

CORPORATIONS MAKE A SUBSTANTIAL CONTRIBUTION TO GLOBAL GREENHOUSE GAS (GHG) EMISSIONS. IN 2010, IT WAS estimated that the direct emissions of the world's 500 largest publicly listed corporations (the Global 500) accounted for 11% of total anthropogenic GHG emissions (CDP, 2010). Given the scale of corporate emissions, governments, investors, non-governmental organization (NGOs), and consumers frequently call for corporations to adopt GHG reduction policies, to monitor and measure their emissions, to assign responsibility for emissions to managers, and to report these actions and outcomes to stakeholders (Hoffman, 2006; Gouldson & Sullivan, 2007; Lee, 2012; Weinhofer & Busch, 2013).

Many large corporations have responded to these pressures and adopted carbon management practices (CMPs) in recent years. For example, the proportion of the Global 500 with GHG emissions reduction targets increased

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from 43% in 2004 to 50% in 2010, and to 82% in 2012. The proportion of corporations that had allocated responsibility for climate-change-related issues to their board and/or senior management increased from 56% in 2006 to 85% in 2010, and to 96% in 2012 (CDP 2006; 2010; 2012).

Within the broader sphere of corporate energy and environmental management, there is a rapidly emerging literature that focuses specifically on carbon management practices (Hoffman, 2006; Pinkse & Kolk, 2009; Lee, 2012; Boiral *et al.*, 2012; Weinhofer & Busch, 2013). This literature, which makes ample use of case studies, tends to find that the adoption of specific management practices can lead to corporation-level changes in energy use or GHG emissions (Bloom *et al.*, 2010; Bloom & van Reenan, 2010). However there have been few quantitative tests of the broad hypotheses proposed by this literature, with some exceptions (Theyel, 2000; Bloom *et al.*, 2010; Matsumura *et al.*, 2011).

Other research has questioned whether environmental management practices actually influence corporate environmental performance (Dahlström *et al.*, 2003; Ramus & Montiel, 2005; Wu & Teng, 2014). Some see the adoption of carbon management practices as a form of 'greenwash' designed to legitimize existing corporate practice rather than change it (Greer & Bruno, 1996). Others even suggest these practices can be counterproductive to long-run improvements in corporate environmental performance by delaying the deep, transformative changes that appear to be ultimately needed to address pollution and resource over-use at their root (Konnola & Unruh, 2007).

To our knowledge there is no large-scale empirical study of the impact of CMPs on GHG emissions across large corporations. One reason is the difficulty of generating and obtaining structured quantitative data on corporate CMPs themselves, given that there are few mandatory requirements on corporations to measure or report on their GHG emissions or management practices in a way that is consistent across corporations and countries.

In recent years, however, many of the world's largest corporations have voluntarily disclosed this information to the Carbon Disclosure Project (CDP). Over 80% of the world's largest 500 corporations now voluntarily provide information to the CDP (CDP, 2012). Their responses include information on senior management responsibilities for climate change, climate change risk management strategies, climate change policies, actions directed at reducing GHG emissions, capital investments and payback periods, objectives and targets, and GHG emissions calculation methodologies and assumptions.

To our knowledge, these are the most comprehensive and authoritative data available linking the presence of CMPs and the extent of their implementation, to carbon emissions at the level of the corporation. We use these data to explore a simple question in the remainder of this paper: is there an observable relationship between the application of CMPs in the world's largest corporations and the GHG emissions these practices are intended to reduce?

Research Approach, Data and Methodology

We address this question by constructing a new dataset that is organized at the level of the corporation-year, by developing a simple model to explain the change in GHG emissions intensity within each corporation from 2009 to 2010, and by fitting the data to the model by simple ordinary least squares regression. We are interested in whether the explanatory variables of interest associate negatively with changes in emissions per unit of turnover.

We constructed the dataset from three separate sources. The first is the CDP survey of large corporations, which tells us the level of GHG emissions.[1] The second is publically reported financial information about each corporation such as turnover, assets, and employee numbers. These data we obtained from the Orbis database through Bureau Van Dijk. The third is the information about CMPs that are applied in each corporation. These data were assembled by a company called ENDS Carbon, which used proprietary techniques (explained below) to extract information about the CMPs from the raw responses of corporations to the CDP survey.

The emissions data that form the basis for our dependent variable capture scope 1 and 2 emissions rather than emissions associated with the entire life cycle of the product the corporation sells.[2] We focus on this variable because we expect corporations to have greater control over scope 1 and 2 emissions. We constructed the dependent

[1]For the 2012 version of the CDP questionnaire, see https://www.cdproject.net/CDP%20Questionaire%20Documents/Investor-CDP-2012-Information-Request.pdf

[2]Scope 1 emissions are direct emissions from sources that are owned or controlled by the corporation, and scope 2 emissions are indirect GHG emissions from consumption of purchased electricity, heat or steam.

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variable as the change in emissions intensity (i.e., emissions per $ of operating revenue) because variations in accounting and reporting conventions in voluntarily reported emissions data can create difficulties in comparing the level of emissions across corporations. However, looking at changes over time within individual corporations controls for this variation and gives grounds for more accurate measurement (Sullivan & Gouldson, 2012).

Our independent variables of interest are 23 distinct CMPs that may have been implemented by these corporations by 2010. Table 1 describes these CMPs in detail. The complete dataset we received from ENDS Carbon contained 1627 corporation-year observations of emissions, and CMP scores for 582 unique corporations.[3] These were the most up-to-date data available to us from the most recently publically available survey results.

Using the CMPs as independent variables to explain the change in emissions intensity is a novel contribution of our study. To construct the CMP data, ENDS Carbon's analysts assigned a CMP-specific score to each corporation based on the corporation's responses to certain questions in the CDP questionnaire. For example, the corporation's response to the question, 'Are carbon emissions verified by a third party?' fed into ENDS Carbon's assessment of the depth of assurance for the corporation's emissions (i.e., D01 in Table 1). A corporation's response to the question, 'Has the company made an explicit corporate policy commitment to limit or reduce carbon emissions?' fed into the assessment of the presence and extent of corporate policy commitments to deal with emissions (P01 in Table 1).

ENDS Carbon performed the scoring according to a framework that it developed in line with the ISO 14064 standard for quantifying, monitoring, reporting and verifying GHG emissions. ISO 14064 is, in turn, based on the GHG Protocol, an international GHG accounting framework developed by the World Resources Institute and the World Business Council for Sustainable Development.

ENDS Carbon grouped the 23 CMPs into four broader management practice categories: 'Policy and Targets (P#)', 'Measurement (M#)', 'Management and Decision-making (DM#)' and 'Disclosures' (D#), where # varies within each category to indicate a specific CMP. Table 2 gives an example of the scoring criteria applied to one CMP and Table A1 in the appendix gives criteria for scoring maximum points for each CMP. [4]

In our analysis we interpret a zero CMP score as the absence of that practice from the corporation's overall carbon management strategy during the year the scores were assigned. It is important to highlight that the scores refer to the state of the corporation's management practices in 2010, the only year for which we have CMP data. We interpret a non-zero score as the presence of the practice. When the practice is present in a corporation, we interpret a higher score to mean that the technique has been implemented to a 'greater extent'.

The differences in the scales, which ENDS Carbon used when scoring individual CMPs, are arbitrary for the purposes of this paper. For example, in the raw data 'M04: GHG accounting methods' is scored on a scale from 0 to 4 whereas 'P01: Policy and commitments' uses a 0 10 scale. For convenience we re-scaled the scoring ranges in the raw data provided to us by ENDS Carbon to a common range of 0 to 5. This is reflected in descriptive statistics given in Table 3. This merely makes the scoring ranges of the CMPs comparable. It should be kept in mind that only the sign and statistical significance of the estimated coefficients matter when interpreting the regression results below. In other words, relative magnitudes of the coefficients are uninformative.

While ENDS Carbon produced CMP scores for 582 unique corporations, we used data for 433 of these in our analysis as we required corporations to have reported in both 2009 and 2010 and not all did. We restricted our sample in this way to avoid what we call the time-order problem. That is, if we were using the whole dataset covering 2007 2010, the independent variable observations of interest (the CMPs) which were only measured once, in 2010, would come after most of the dependent variable observations (measured in 2007 2010) in time. This would introduce ambiguity in the interpretation of the coefficients and make it impossible to draw any inference on the direction of causality between dependent and independent variables.

Although our dataset is novel and rich in several ways, allowing us to investigate the question above, it is important to note that it does not constitute a random sample. Most large, publically traded corporations are invited by CDP to respond to the CDP survey but those that respond do so voluntarily. Prior research on the characteristics of corporations that disclose their GHG emissions voluntarily has found that a corporation is more likely to disclose if it is in a relatively clean sector, if it has superior environmental performance relative to its peers, and if the proportion of reporting corporations in its sector is high (Brouhle & Ramirez-Harrington, 2009; Matsumura

[3]For reasons discussed below, we are only able to use a subset of this dataset in our analysis.
[4]A detailed scoring scheme for each CMP similar to that reported in Table 2 is available on request.

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	Label (Tag)	Description
POLICY	Policy & commitments (P01)	Extent to which corporation identifies emissions and climate change explicitly as issues to be managed through commitments and targets.
	Direct emissions targets: scope and structure (P02)	Quality of the corporation's emissions targets and the share of its scope 1 and 2 emissions the target addresses.
	Indirect emissions target (P03)	Presence and quality of the corporation's scope 3 emissions target.
	Target strength (P04)	Ambitiousness of the corporation's scope 1 and 2 emissions target relative to its global sector peers.
	Target horizon (P05)	Length of the time horizon over which the emissions target is to be achieved.
MEASUREMENT	Scope 1 and 2 emissions measurement (M01)	Accuracy of the emissions measurement system implemented by the corporation for scope 1 and 2 emissions.
	Scope 3 emissions measurement (M02)	Number of relevant Scope 3 emissions sources reported.
	Boundary policy quality (M03)	Consistency and continuity of the boundary within which emissions are measured (e.g. equity share, financial/ operational control approaches, etc.)
	GHG accounting methods (M04)	Degree of recognition of emissions accounting standard used by the corporation, and the consistency of implementation of the standards over time.
	Activity intensity (M05)	Number of activity intensity metrics (e.g. emissions per unit of output) the corporation uses to measure emissions performance.
	History [reporting] (M06)	Number of years in which the corporation reported emissions.
DECISION MARKING	Risk awareness – depth (DM01)	Number of relevant risks recognized and assessed by the corporation and whether the corporation identifies key sector-specific risks.
	Opportunity awareness (DM02)	Number of relevant opportunities recognized by the corporation and whether the corporation identifies key sector-specific opportunities.
	Responsibilities (DM03)	Level at which the emissions management responsibility lies in corporation's management hierarchy and the length of time it has been there
	Incentive structures (DM04)	Extent to which the corporation uses staff incentives for meeting emissions related goals.
	Emissions in corporate strategy (DM05)	Extent to which the corporation has integrated emissions management into its strategic planning, risk management and business strategy activities.
	Carbon investment drivers (DM06)	Number and quality of abatement measures identified by the corporation
DISCLOUSRE	Fundamental disclosures (D01)	Completeness of the corporation's disclosure regarding its emissions management activities
	Disclosures: information availability (D02)	Variety of media through which the corporation publically releases at least two years of emissions data
	Segmental disclosures (D03)	Resolution at which the corporation releases emissions data into public domain (e.g. line of business, business unit/division)

(Continues)

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Label (Tag)	Description
Assurance breadth (D04)	Whether one or more of scope 1, 2, or 3 emissions are independently and externally verified. (e.g. scope 1 and 2 are verified but not scope 3)
Assurance depth (D05)	Share of corporation's emissions which are independently and externally verified. (e.g. 75% of reported scope 1 and 2 emissions are verified)
Assurance quality (D06)	Reputability of the assurance process used.

Table 1. Carbon management practices (CMPs) studied
Notes:
1) The descriptions above summarize the methodological details provided by ENDS Carbon. Additional information is available upon request.
2) The criteria used in assigning the top score for each CMP is provided in Table A1 in the Appendix.

Points	Criterion
0	Evidence of direct emissions targets cannot be established
0	No identifiable targets set
1	Targets set cannot be converted to Annual Equivalent Targets (AETs) and may cover both direct and *indirect* emissions
2	Well specified target(s) address some scope 1 or 2 emissions
3	Well specified target(s) address ≥50% of aggregate global scope 1 & 2 emissions
4	Well specified target(s) address ≥75% of aggregate global scope 1 & 2 emissions
5	Well specified target(s) address 100% of aggregate global scope 1 & 2 emissions

Table 2. Scoring criteria for 'P02: Direct emissions targets: scope and structure'
Notes:
1) The criteria used in assigning the top score for each CMP is provided in Table A1 in the Appendix. Additional information is available on request.

et al., 2011). Nevertheless, the CDP is widely seen as the most comprehensive data source on corporate climate change practices and performance. We are not aware of any other large-N dataset containing information about carbon-specific management practices, meaning the CDP data, despite its challenges, is the best available. Our final dataset includes corporations from 39 sectors and 15 countries, and contains sufficient scale and variation for meaningful regression analysis.

Model and estimation results

To model the relationship of interest statistically, we fit the data described above to the following equation:

$$\Delta ln(co2_i/oprev_i) = \alpha + M_i\boldsymbol{\beta} + S_i\boldsymbol{\zeta} + C_i\boldsymbol{\theta} + ln(emp_i)\pi + \boldsymbol{\varepsilon}_i \quad (1)$$

where i indexes corporations. Our dependent variable measures the log change from 2009 to 2010 in GHG emissions normalized by the operating revenues of corporation i. More specifically the dependent variable is calculated as,

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Variable	Obs	Mean	Std. Dev.	Min	Max	Source
ln(co2)	1627	12.587	2.541	4.111	18.999	CDP
ln(oprev)	1603	4.119	1.643	-4.605	8.430	ORBIS
ln(co2/oprev)	1603	8.490	2.096	1.417	19.595	
Δ ln(co2/oprev)	1022	-0.039	0.536	-7.002	2.282	
ln(emp)	1408	5.170	1.611	-0.892	8.726	ORBIS
P01: Policy & commitments	1627	4.473	1.015	0	5	ENDS
P02: Direct emissions targets	1627	2.459	2.299	0	5	ENDS
P03: Indirect emissions target	1627	1.227	2.042	0	5	ENDS
P04: Target strength	1627	1.763	2.048	0	5	ENDS
P05: Target horizon	1627	2.357	2.207	0	5	ENDS
M01: Scope 1&2	1627	2.786	1.676	0	5	ENDS
M02: Scope 3	1627	2.186	1.908	0	5	ENDS
M03: Boundary policy	1627	2.891	1.741	0	5	ENDS
M04: GHG accounting methods	1627	1.602	2.057	0	5	ENDS
M05: Activity intensity	1627	4.184	1.749	0	5	ENDS
M06: History	1627	3.398	1.981	0	5	ENDS
DM01: Risk awareness - depth	1627	2.649	2.018	0	5	ENDS
DM02: Opportunity awareness	1627	2.966	2.082	0	5	ENDS
DM03: Responsibilities	1627	3.412	1.821	0	5	ENDS
DM04: Incentive structures	1627	1.121	1.333	0	5	ENDS
DM05: Emissions in corporate strategy	1627	3.800	1.759	0	5	ENDS
DM06: Carbon investment drivers	1627	3.844	1.902	0	5	ENDS
D01: Fundamental disclosures	1627	4.001	1.437	0	5	ENDS
D02: Disclosures: information availability	1627	2.410	1.513	0	5	ENDS
D03: Segmental disclosures	1627	2.924	1.561	0	5	ENDS
D04: Assurance breadth	1627	2.290	2.151	0	5	ENDS
D05: Assurance depth	1627	2.341	2.369	0	5	ENDS
D06: Assurance quality	1627	2.052	2.143	0	5	ENDS

Table 3. Summary statistics
Notes:
1) ln(co2) is the natural log of the sum of scope 1 and 2 emissions measured in tons of CO2e.
2) ln(oprev) is the natural log of operating revenue measured in millions of nominal US$.
3) Δ ln(co2/oprev) is the change in ln(co2/oprev) between 2009 and 2010.
For details regarding individual carbon management practices see Tables 1.

$$\Delta ln(co2_i/oprev_i) = ln(co2_i/oprev_i)_{2010} - ln(co2_i/oprev_i)_{2009} \quad (2)$$

The dependent variable accounts for the heterogeneity of individual corporations not captured elsewhere because it is expressed in log changes.

On the right hand side of Eqn (1), matrix M_i contains the data on CMP scores. M_i is time-invariant since we only observe it in the ENDS Carbon data for one year, 2010. S_i contains the dummy variables for secondary and tertiary sectors. C_i contains the dummy variables for European Union, Japan, and Australia, which are equal to one if the corporation is European, Japanese, and Australian, respectively.[5] Since change in emissions might be sensitive to corporation size even after normalization, the log of employment is included to account for the scale of the corporation. The term α is an intercept and ε is an i.i.d. error term. Table 3 gives descriptive statistics for all variables.

[5]The reference group consists of corporations from non-EU European countries, i.e., Norway and Switzerland.

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We estimate (1) using simple ordinary least squares. The coefficients of interest are in the vector $\boldsymbol{\beta}$. The results are reported in Table 4.

We focused on the key patterns that emerged from our analysis. When we analyzed the entire dataset of 433 corporations (column 1), we found no statistically significant evidence that any of the 23 carbon management practices had influenced corporate GHG emissions. To test whether this was as a result of limitations in the quality of the data on corporate GHG emissions, in column 2 we repeated the analysis but restricted the sample to those corporations that were assessed by ENDS Carbon to have better than average quality of GHG emissions measurement.[6] Again we found no statistically significant evidence that the take-up and implementation of any of the 17 management practices has impacted on GHG emissions.

We then excluded the financial sector from the sample (column 3), on the basis that corporations within this sector are likely to have lower levels of direct emissions. This additional restriction can account for some of the self-selection effects that make the sample non-random. As discussed above, prior research has found that corporations that are in relatively clean sectors are more likely to voluntarily disclose their emissions. Figure 1 illustrates the distribution of corporations in our dataset across sectors.

For this sub-sample, which only includes non-financial sector corporations with better-than-average quality of GHG measurement, we found some evidence of an impact of CMPs on emissions performance. Column 3 shows lower levels of emissions growth for corporations with stronger policies and commitments in place to address climate change, for corporations with explicit emissions reduction targets, and for corporations that created financial incentives for emissions reduction. However, we did not find an observable impact for any of the 14 other CMPs.

This suggests little discernible impact on emissions performance for all the other CMPs that we consider. They include the extent to which responsibilities for carbon management have been assigned to a member of the board, the quality and quantity of GHG-related information disclosure, and the quality of assurance of reported GHGs. This finding is clearly at odds with the expectation in the literature that the presence and implementation of CMPs should improve corporate GHG performance.

In columns 4 and 5 we restrict the sample further to include only the 'dirty' corporations or only the corporations that are in the sectors that are regulated under the European Emissions Trading Scheme (ETS).[7] This greatly reduces the size of the estimation sample but produces similar results. Moreover, those few CMPs which are significant in each of columns 3 to 5 are not consistently so across columns, with the exception of target strength which is negative and significant in columns 4 and 5. Taken together these observations align well with our main conclusion that it is not possible to identify a statistically significant association between most CMPs and emissions performance.

It is important to mention that we tested and eventually rejected for methodological reasons a wide range of estimation approaches in arriving at the preferred specifications in Table 4. We tried various dependent variable measures including absolute emission levels rather than emissions relative to output (the results were largely the same). We ran purely cross-sectional estimations exploring the simple direction, strength, and significance of association between emissions and the CMPs, as opposed to the estimations of the relationship presented here. We tried constructing a single index of the CMPs rather than including the CMPs individually. We tried grouping the CMPs into their different management practice categories and, separately, including just the CMPs that might be expected to reduce emissions directly and omitting those that might contribute to emissions reductions indirectly. We explored binary and continuous measures of the individual CMPs themselves. We feel that the extensive tests we subjected the data to in arriving at the preferred estimation strategy described above, and reflected in the specifications and results in Table 4, have ensured the best practicable methodological treatment of the data given their inherent challenges.

Discussion of Results

We propose three possible explanations for these results, all of which have significant implications for policy and practice. The first is that whilst the most comprehensive and authoritative available data on corporations and

[6]Specifically, the sample includes only those corporations whose aggregate measurement score is greater than or equal to the median of the aggregate score across all corporations. We denote these as corporations with a 'high quality of measurement'.
[7]Table A2 in the appendix shows which corporations were considered to be subject to the ETS, on the basis of their industry sector.

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Dep. Var: $\Delta ln(co2_i / oprev_i)$	(I) All corporations		(II) High quality measurement		(III) Excl. financial sector		(IV) Only 'dirty' sectors		(V) Only ETS sectors	
	β	s. e.	β	s. e.	β	s. e.	β	s. e.	β	s. e.
Po1: Policy & commitments	-0.008	(0.048)	-0.052	(0.040)	-0.067**	(0.031)	-0.067	(0.047)	-0.123	(0.097)
Po2: Direct emissions targets	-0.020	(0.015)	-0.001	(0.016)	0.000	(0.013)	0.018	(0.020)	0.064	(0.044)
Po3: Indirect emissions target	0.008	(0.011)	0.010	(0.009)	0.008	(0.009)	0.019	(0.012)	0.013	(0.021)
Po4: Target strength	0.007	(0.013)	-0.017	(0.013)	-0.007	(0.012)	-0.031*	(0.017)	-0.070**	(0.027)
Po5: Target horizon	0.018	(0.014)	0.022	(0.013)	0.019*	(0.011)	0.009	(0.013)	0.019	(0.027)
DMo1: Risk awareness - depth	-0.008	(0.011)	0.004	(0.009)	0.009	(0.008)	0.011	(0.009)	0.030	(0.020)
DMo2: Opportunity awareness	0.002	(0.012)	-0.009	(0.011)	-0.004	(0.010)	-0.006	(0.011)	-0.012	(0.024)
DMo3: Responsibilities	-0.019	(0.016)	-0.009	(0.013)	-0.007	(0.012)	-0.021	(0.014)	-0.038*	(0.021)
DMo4: Incentive structures	-0.009	(0.014)	-0.021	(0.014)	-0.029**	(0.013)	-0.017	(0.014)	-0.019	(0.027)
DMo5: Emissions in corporate strategy	0.035	(0.034)	0.034	(0.024)	0.018	(0.019)	0.017	(0.039)	-0.050	(0.104)
DMo6: Carbon investment drivers	0.020	(0.026)	0.001	(0.017)	0.006	(0.018)	-0.010	(0.022)	-0.058	(0.040)
Do1: Fundamental disclosures	-0.022	(0.035)	0.005	(0.022)	0.006	(0.021)	0.028	(0.029)	0.039	(0.062)
Do2: Disclosures: information availability	0.004	(0.022)	0.008	(0.015)	0.009	(0.014)	-0.003	(0.015)	-0.011	(0.019)
Do3: Segmental disclosures	0.027	(0.019)	0.016	(0.014)	0.008	(0.014)	-0.013	(0.014)	-0.047	(0.055)
Do4: Assurance breadth	-0.012	(0.016)	-0.014	(0.014)	-0.005	(0.014)	0.002	(0.016)	-0.047**	(0.023)
Do5: Assurance depth	0.003	(0.012)	0.018	(0.013)	0.018	(0.013)	0.005	(0.015)	0.020	(0.029)
Do6: Assurance quality	0.005	(0.012)	-0.012	(0.012)	-0.010	(0.012)	-0.009	(0.017)	-0.026	(0.019)
Mo1: Scope 1&2	-0.016	(0.021)								
Mo2: Scope 3	-0.011	(0.012)								
Mo3: Boundary policy	0.017	(0.016)								
Mo4: GHG accounting methods	0.010	(0.012)								
Mo5: Activity intensity	-0.027	(0.025)								
Mo6: History	0.027	(0.018)								
Employment	-0.003	(0.015)	-0.003	(0.014)	-0.004	(0.012)	0.002	(0.015)	0.016	(0.017)
Constant	-0.187	(0.189)	-0.055	(0.191)	0.019	(0.176)	0.201	(0.273)	1.111**	(0.452)
Number of observations	433		251		220		119		47	
R-squared	0.068		0.105		0.166		0.221		0.504	

Table 4. Dependent variable: First difference of log of CO_2 emissions per million US$ of operating revenue

Notes:

1) Columns (I)-(V) of the table differ in the samples used in estimation. In (I) all corporations are included, whereas in (II) the sample is restricted to corporations with a high quality of measurement defined as those which score at least as good as the mean corporation in the distribution of (Mo1 + Mo2 + ... + Mo6). In addition to the high quality of measurement restriction, columns (III)-(V) are subject to sector restrictions. Specifically, in column (III), banks and corporations operating in the financial sectors are excluded. In column (IV) the sample is restricted to the corporations operating in the dirty sectors. Column (V) includes only EU corporations operating in the sectors regulated under the ETS.

2) For description of the independent variables see Table 1 and A2, and for the definitions of the sectors see Tables A3.

3) All regressions include dummies for secondary and tertiary sectors. EU, Japan and Australia dummies are included in (I)-(IV) but not in (V).

4) Robust standard errors are provided in parentheses with

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

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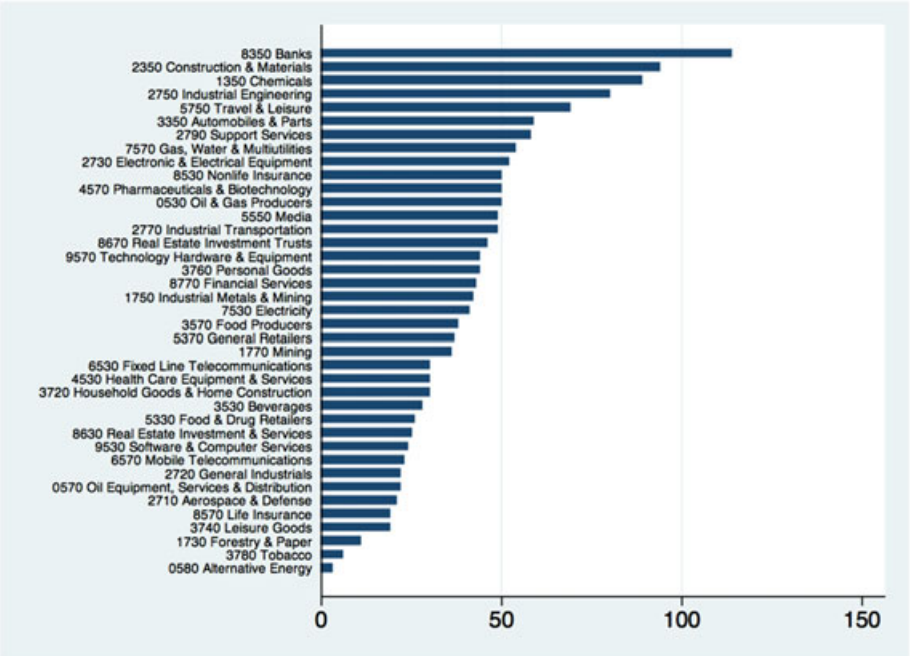

Note: the corporations in the dataset represent 39 economic sectors. Consistent with prior research that has found that corporations are more likely to disclose their emissions if they reside in a relatively clean sector [20, 21], the sector with the largest number of reporting corporations in our data is Banks.

Figure 1. Distribution of corporations by industry sectors

GHG emissions tells us a lot about the implementation of corporate CMPs, it does not reveal the true impact of these practices on GHG emissions. This could be because of self-selection issues in the corporations that choose to report to CDP or because the data that the corporations supply is incomplete or inconsistent. These reasons could indicate that more standardized forms of corporate emissions accounting, monitoring and disclosure are needed. This in turn feeds into the debate on the limitations of voluntary reporting of corporate environmental performance and on the potential benefits of standardized, mandatory reporting (Kolk *et al.*, 2008; Sullivan & Gouldson, 2012).

The central argument for the introduction of standardized mandatory reporting is as follows. The more complete and consistent are the data about corporate carbon management and GHG emissions, the easier it will be for stakeholders (including those within the corporations themselves) to monitor progress, to compare performance, and to exert influence. However, even if a mandatory reporting requirement were introduced, it is likely that this would only be a partial solution. Evidence from other mandatory schemes suggests that corporations could retain significant flexibility in the ways they measure and report their emissions (Gouldson & Sullivan, 2007). Furthermore, in the absence of a global agreement on corporate carbon reporting, differences between national schemes will make it difficult to compare the data produced from different jurisdictions (Sullivan & Gouldson, 2007). Our experience with what is to our knowledge the most comprehensive quantitative data on corporate emission and CMPs suggests mandatory reporting procedures based on fully random sampling of corporations could go a long way to helping corporate managers understand which CMPs are most effective.

The second possible explanation is that the implementation of these CMPs may not lead to immediately observable reductions in GHG emissions. Whilst many analysts highlight the availability of some 'early wins' (through the adoption of measures with very short payback periods, often referred to as 'low-hanging fruit') in energy and carbon management (DeSimone & Popoff, 2000; Shipley & Elliot, 2006), it may be that corporations have already exploited these measures by the time they implement the CMPs they describe in their reporting to CDP. The consequence is that it may take time for the impacts of CMPs to become observable. There has been some

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evidence of this delayed impact elsewhere (Wu & Teng, 2014). Even so, in a context where many analysts have highlighted the need for rapid reductions in emissions to avoid dangerous climate change, the extent of this delay becomes critically important.

The third possible explanation is that the CMPs that are being implemented by a large proportion of the world's largest corporations are not sufficiently impact-oriented. Corporations might be assuming that the mere presence of different CMPs is reducing their GHG emissions without assessing the extent to which the CMPs are actually doing so. Expressed more directly, it could be that more attention should be paid not to the presence but to the impact of corporate CMPs on the emissions that they are supposed to be reducing.

While these are all – individually or collectively – important conclusions, they should be qualified by noting that we have only been able to analyze a relatively small proportion of all corporations that report emission to CDP. While we have tested a wide range of estimation methods, we have only been able to study a limited time period with the available data. That is, our results describe a short-run relationship between CMPs and GHG emissions performance. More extensive future analysis may point to a more broadly recognizable relationship. Research priorities in this area are therefore to consider a larger, random sample of corporations over longer time periods.

Due in part to the non-random nature of our sample, these results should not be interpreted as applying to individual corporations or to the universe of corporations from which the CDP data is drawn. There may well be corporations that have delivered significant GHG reductions as a result of adopting the sort of CMPs discussed here.

Finally, we note that there may be an element of reverse causality in our analysis. In that context, we would need to consider whether it is the level, or the rate of change, of GHG emissions that drives the implementation of a CMP (rather than, as we considered, whether the CMP drives GHG emissions). For instance, a positive coefficient on a management practice variable may suggest that corporations with a high emissions intensity growth rate are more likely to implement that practice because reducing energy costs is a stronger imperative for dirty corporations than for clean ones. Or it might be the case that corporations with a high growth rate are subject to a specific policy requiring the adoption of new forms of environmental management.

Conclusions and Implications

It is something of an article of faith among policymakers, investors, and companies that good corporate management practices will inevitably lead to better performance (in terms of GHG emissions) outcomes. This assumption has underpinned many of the public policy measures and corporate management initiatives directed at reducing corporate GHG emissions. The fact that, even using the most comprehensive and authoritative data on carbon-specific CMPs and applying the best practicable estimation methods available, we have found limited evidence of an impact of CMPs on corporate carbon emissions is therefore of profound importance, to policymakers, to companies and to society as a whole.

However, our analysis does not tell us is whether this finding is because of limitations in the data that are available, because of the absence of a causal relationship between CMPs and performance, or because companies do not place sufficient emphasis on performance or outcomes in their carbon management initiatives. This paper therefore points to three important recommendations for companies.

The first is that companies need to strengthen the quality and comparability of their reporting to the CDP. This requires that they align their reporting with the World Business Council's Greenhouse Gas Reporting Protocol (WBCSD, 2004; 2011), that they clearly define the scope and boundaries of their reporting, that they have a consistent approach to calculating and reporting their emissions, that they clearly document the assumptions, protocols and emissions factors they use in their reporting, and that they have their data independently assured (e.g. the proposals in Sullivan & Gouldson, 2012).

The second is that companies need to explicitly discuss how the adoption of corporate management practices influences corporate greenhouse gas emissions. At present, the CDP encourages companies to explain the contribution that specific actions (e.g. the adoption of particular energy saving technologies, the changing of fuel or electricity sources) makes to their greenhouse gas emissions. Generally, this is presented in terms of the quantity of greenhouse gas emissions avoided or abated. While helpful, this is not sufficient to answer the questions raised

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by this paper. Ideally companies should explain how the carbon management practices they have adopted have influenced the carbon management actions that they have taken. In turn, they should explain how these actions have both contributed to GHG emissions avoided or abated (as they do at present) and how these actions, together, have influenced the company's total GHG emissions. The CDP is moving in this direction as it encourages companies to provide some high level explanation of overall changes in their greenhouse gas emissions. However, to date, this relationship between carbon management practices, actions, and performance is not clearly drawn for the vast majority of companies.

The third is that companies need to shift their focus from relative to absolute performance. That is, they should express their targets in terms of the absolute GHG emission reductions they are looking to achieve, and they should ensure that their management practices and processes are directed towards this end (i.e., of reducing absolute emissions rather than seeking to improve energy efficiency or energy intensity). We recognize that this is a demanding recommendation although we note that there is evidence that companies can deliver consistent year-on-year reductions in their greenhouse gas emissions over a decade or more (Sullivan & Gouldson, 2013), and that leading companies are prepared to commit to absolute emission reduction targets that extend over multiple decades (Gouldson & Sullivan, 2013).

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Appendix

	Tag	Label	Criteria for awarding maximum score
POLICY	P01	Policy & commitments	Carbon commitments include one or more specific carbon reduction targets.
	P02	Direct emissions targets: scope and structure	Well specified target(s) address 100 percent of aggregate global scope 1 & 2 emissions.
	P03	Indirect emissions target	Well specified target(s) address one or more specific Scope 3 emissions.
	P04	Target strength	Annual Equivalent Target can be calculated and in the top 10% of global sector peers.
	P05	Target horizon	Current active target portfolio includes AchieveBy >5 and up to 20 years from announcement year.
MEASUREMENT	M01	Scope 1&2	Scope 1 & 2 emissions measurement is routine (annual) and accurate (>95% in latest period).
	M02	Scope 3	Measures ≥3 relevant scope 3 emissions (in latest period).
	M03	Boundary policy	Financial control / equity share policy applied in each trend year.
	M04	GHG accounting methods	Consistent industry or global standard applied in all reporting periods under review.
	M05	Activity intensity	Calculates one or more commonly used intensity metrics (used by >25% of sector peers).
	M06	History	History exceeds 5 years beginning in 2005 or earlier per CDP and/or CSR returns.
DECISION MAKING	DM01	Risk awareness – depth	Risks identified include dominant sectoral risks (Among top 2 sector risks).
	DM02	Opportunity awareness	Opportunity identified includes dominant sectoral opportunity (Among top 2 sector opportunities).
	DM03	Responsibilities	Responsibility has consistently rested at Board level (over 3 periods) incl. Current year.
	DM04	Incentive structures	Staff at highest responsibility level responsible for meeting climate & carbon goals are incentivized, with monetary incentives.
	DM05	Emissions in corporate strategy	Company engages with policy makers to encourage further action on climate change mitigation and / or adaptation.
	DM06	Carbon investment drivers	Methods identified include globally common methods (global good practice = Top 4).
DISCLOSURE	D01	Fundamental disclosures	All of the following are disclosed in the public domain: GHG / climate policy; GHG emissions data (numerical disclosures); carbon commitments including targets; carbon commitments including targets; carbon accounting policies (both boundary and method).
	D02	Disclosures: information availability	Publishes emissions data and 1 year comparative figures in 3 of the following: CDP disclosure; corporate sustainability or related website; annual sustainability report.
	D03	Segmental disclosures	Segmental analysis of emissions follows that in the annual report and accounts
	D04	Assurance breadth	Assurance covers >0 percent of scope 1, 2 and 3 emissions
	D05	Assurance depth	> 90 percent of all disclosed emissions subject 3rd party assurance or verification.
	D06	Assurance quality	Reasonable Assurance (Includes 'Verification' option in CDP Questionnaire dropdown).

Table A1: Criteria for awarding maximum score for each carbon management practice (CMP)

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	Dirty	ETS	Primary	Secondary	Tertiary
Aerospace & Defence	*			*	
Alternative Energy				*	
Automobiles & Parts	*			*	
Banks					*
Beverages	*			*	
Chemicals	*	*		*	
Construction & Materials	*			*	
Electricity	*	*	*		
Electronic & Electrical Equipment	*			*	
Financial Services					*
Fixed Line Telecommunications					*
Food & Drug Retailers					*
Food Producers	*			*	
Forestry & Paper	*	*	*		
Gas, Water & Multiutilities	*	*	*		
General Industrials	*			*	
General Retailers					*
Health Care Equipment & Services					*
Household Goods & Home Construction	*				*
Industrial Engineering					*
Industrial Metals & Mining	*	*	*		
Industrial Transportation	*			*	
Leisure Goods	*			*	
Life Insurance					*
Media					*
Mining	*	*	*		
Mobile Telecommunications					*
Nonlife Insurance					*
Oil & Gas Producers	*	*	*		
Oil Equipment, Services & Distribution	*		*		
Personal Goods					*
Pharmaceuticals & Biotechnology					*
Real Estate Investment & Services					*
Software & Computer Services					*
Support Services					*
Technology Hardware & Equipment	*			*	
Tobacco	*			*	
Travel & Leisure	*				*

Table A2: Relevant classifications

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