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The relations between corporate economic performance,
environmental disclosure and greenhouse gas emissions: new insights.

Omaima A. G. Hassan and Peter Romilly

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Corresponding author:

Dr Omaima Hassan

Department of Accounting and Finance
Aberdeen Business School
Robert Gordon University
Aberdeen
AB10 7QB
Scotland, UK
Email: o.hassan@rgu.ac.uk
Phone: +44 (0)1224 26 3929

Co-author information:

Dr Peter Romilly
Ecmetrika Consultancy & Research
Newport on Tay
DD6 8JF
Scotland, UK
Email: peter.romilly@greenisp.co.uk
Phone: +44 (0)7929 51 9473

The relations between corporate economic performance, environmental disclosure and greenhouse gas emissions: new insights.

Abstract

This study examines the associations and causations between corporate economic performance, environmental disclosure and greenhouse gas emissions, utilising a large, longitudinal, multi-country dataset disaggregated between developed and developing countries. The methodology employs a simultaneous equation model with system estimation to deal with endogeneity between the variables, and Granger causality tests to indicate their direction of causation. A robust result is that lower emissions are strongly associated with better economic performance. After pretesting for stationarity, we find evidence of a one-way causation from emissions and environmental disclosure to economic performance, but no evidence of reverse causation. We also find strong evidence of a one-way causation from emissions to disclosure, but no evidence of reverse causation. The over-arching policy implication is that environmental performance, as measured by greenhouse gas emissions, plays a crucial role in the formulation of business strategy at firm level and government environmental policy at national and international levels.

Key words: economic, environmental, performance, disclosure, greenhouse gases, environmental policy.

1. Introduction

Prior studies typically focus on the pairwise associations between corporate economic performance (CEP), environmental disclosure (CED) and environmental performance using cross-sectional analysis based on small samples and one or a few countries. The proxies used for environmental disclosure and performance often suffer from measurement issues. By contrast, the current study employs a large-scale, longitudinal, multi-country dataset to analyse both the associations and causations between the variables, and utilises relatively new measures for environmental disclosure and performance, i.e. the Bloomberg environmental disclosure score and greenhouse gas emissions (GHG) respectively. These provide consistent, comparable measures across companies, countries and time, increasing the replicability of our results and hence their comparability with future studies.

Given potential endogeneity between CEP, CED and GHG, we employ a simultaneous equation model and system methods to estimate the variable associations. The problem of endogeneity in this context is wider than commonly recognised because studies often analyse the association between two of the three variables without considering the influence of the third. If the three variables are co-determined, such model misspecification will result in biased and inconsistent coefficient estimates. A novel feature of our study is the use of the Granger causality test to examine the direction of causation between the variables of interest. Tests of association are not, strictly speaking, tests of causation, although they are sometimes interpreted as such. The Granger test provides extra information on the nature of the causal relationship between variables.

There are a number of ways to measure environmental performance. Our preferred measure, greenhouse gas emissions (such as carbon dioxide, nitrous oxide and methane),

captures the fundamental influence of corporate economic performance on climate change, i.e. a large-scale, long-term shift in the planet's weather patterns or average temperatures (Met Office, UK). Business sector concern over environmental issues, particularly climate change, has produced a sharper focus and ongoing debate on the relations between CEP, CED and GHG. Two types of business risk are associated with GHG and climate change: the direct effect of climate change through changes in weather patterns, rising sea levels and dangerous changes in patterns of drought and flooding, and the indirect effect via regulatory intervention including abatement and liability costs arising from taxes and trading schemes (Kim and Lyon, 2011, p. 2). These risks constitute significant threats to corporate economic performance generally, and exert pressure on firms to improve their own environmental performance. Risk evaluation is further complicated by the fact that climate change and business risks are distributed unevenly across the globe with significant regional differences (Romilly, 2005; 2007). The central issue is whether it pays firms to be good to the environment and, if so, what the nature of the causality is. Does good economic performance cause good environmental performance, or vice versa, or is there two-way causation? Such differences in causative influence have implications for policy formulation.

Another important issue is how much information a firm should disclose about its environmental performance: should poorer environmental performers disclose more or less information about their performance, bearing in mind the market reaction to such disclosure? The literature provides contrasting theories on the relationship. Voluntary disclosure and signalling theories predict a positive association between environmental performance and disclosure, i.e. better performers disclose more environmental information voluntarily to distinguish themselves from poorer performers. Alternatively, legitimacy theory argues that

poorer performers face socio-political pressures to disclose more environmental information voluntarily to change perceptions and “legitimise” their activities. In this view, it is poorer performers who disclose more. The empirical evidence, however, is mixed. Furthermore, less is known about how environmental disclosure might impact environmental performance both in theory and practice (Luo *et al.*, 2012; Matisoff, 2013; Lewis *et al.*, 2014). Although there is a cost for reporting environmental information, the information can shed light on areas of concern such as “hot spots” in energy consumption, water usage, greenhouse gas emissions, and hazardous and toxic waste, so that companies can take actions to deal with them. The reported information may also help identify and manage risks and opportunities associated with climate change and improve company reputation by adopting a proactive approach (Sullivan and Gouldson, 2012).

The resulting debates have spawned an extensive theoretical and empirical literature on the associations between corporate economic performance, environmental disclosure and environmental performance, but the conclusions from this literature, particularly from empirical studies, are decidedly mixed. Reasons include methodological and measurement problems in the constructs of interest, lack of a temporal dimension in the data, omitted variable bias and inadequate sampling procedures (e.g., McWilliams and Siegel, 2000; Patten, 2002; Clarkson *et al.*, 2008; Endrikat *et al.*, 2014). The prevalence of small samples raises concern over the robustness of the estimation results and limits the ability to generalise findings to different settings (e.g., Walls *et al.*, 2012; Lewis *et al.*, 2014; Zhao and Murrell, 2016).

We do not explore in depth the many theoretical issues in this area, although we do provide background commentary where appropriate. Our focus is on advancing the empirical literature through the analysis of a large-scale dataset using system estimation as well as

Granger causation tests. To the best of the authors' knowledge, no other study in this area (excluding meta-analytic studies) uses as many observations, and no other study uses Granger causation testing. This focus is supported by the observation that, whilst empirical work on the estimated pairwise associations between the variables is voluminous, particularly for cross-sectional data, much less research has been conducted on their contemporaneous association (including appropriate control variables) and their direction of causation (Walls *et al.* 2012; Nollet *et al.* 2016).

The use of cross-section analysis in prior studies (e.g., Freedman and Patten, 2004; Lorraine *et al.*, 2004; Clarkson *et al.*, 2008; Luo and Tang, 2014) imposes a number of limitations, including the representativeness of the examined time period, i.e. the one point in time covered in the analysis, and whether the observed associations among the variables of interest hold over time. Delmas and Blass (2010) highlight the problems of using static data in the case where a firm has a one-time incident in the year in question or when data is not available for the same year for all companies. Also, the omission of temporal considerations may produce unstable results in cross-section analysis (Murray *et al.*, 2006). Perhaps the most significant limitation, however, is the difficulty of identifying causative variable relationships. We employ both cross-section and time series data (panel data), which gives the researcher a larger number of observations, increasing degrees of freedom in statistical testing and reducing the problem of multicollinearity among the explanatory variables, thus improving estimation efficiency (Hsiao, 2002). The availability of time series data enables the use of Granger causation tests, and by considering potential dynamics in the model specification we also respond to research calls to investigate how prior environmental disclosure impacts current environmental performance (Luo *et al.*, 2012; Matisoff, 2013; Lewis *et al.*, 2014).

The current study fills these gaps by examining both the associations and causations between CEP, CED and GHG, utilising a dataset comprising 9,120 firm-year observations from 45 countries worldwide. The analysis is disaggregated between developed and developing countries. The research methodology is as follows. First, we employ a simultaneous equation model to estimate the associations between CEP, CED and GHG. In doing so, we address the issue of variable co-determination by the use of a Hausman test. Second, after pretesting for variable stationarity, we conduct Granger causality tests to determine their direction of causation. The study employs relatively new measures of corporate environmental performance and disclosure to facilitate estimation across countries, companies, and time, as well as a diverse range of firm and country-level variables spanning macroeconomic, environmental, corporate performance and governance characteristics to provide greater control for omitted variable bias.

More specifically, in terms of corporate environmental performance, the literature is largely informed by US studies where researchers tend to use either qualitative rankings such as those of the Council of Economic Priorities (e.g., Freedman and Wasley, 1990; Hughes *et al.*, 2001; Cho and Patten, 2007), or Kinder, Lydenberg, Domini and Company (KLD; recently the MSCI KLD 400 Social Index), or the Toxic Release Inventory (TRI) published by the US Environmental Protection Agency (e.g., Patten, 2002; Al-Tuwaijri *et al.* 2004; Clarkson *et al.*, 2008; Clarkson *et al.*, 2011a). As a result, in a literature review of proxies for corporate environmental performance, Dragomir (2012) conjectures that environmental performance research tends to be localised due to data availability, an observation supported by the lack of larger-scale cross-country studies. In contrast, our measure of environmental performance, i.e. greenhouse gas emissions (millions of metric tonnes), is comparable across countries and

relates directly to what many believe is the greatest existential threat to our planetary well-being, namely climate change (Ibid, p. 225).

In terms of environmental disclosure, Bloomberg's environmental disclosure score provides incremental environmental information over and above what is already known about the firm's environmental performance. The score covers 60 different environmental data points including information about energy consumption and emissions, waste data, environmental initiatives, and environmental policies (see Qiu *et al.* (2016) for a list of these data points). Data sources include companies' annual reports, sustainability reports, press releases and third party research. The common use of content analysis and self-constructed disclosure indices to measure environmental disclosure (e.g., Bewley and Li, 2000; Patten, 2002; Freedman and Patten, 2004; Cho and Patten, 2007; Clarkson *et al.*, 2008, 2011a, 2011b, 2013; Plumlee *et al.*, 2015) has the benefit that such metrics can be designed to fit the project (e.g., country, voluntary and/or mandatory disclosure), but they are mostly subjective and study-specific measures which limit the comparability of estimation results. The Bloomberg environmental disclosure score is more comprehensive, and available for a large number of companies and countries over multiple time periods.

An important and distinctive result from our association tests is the robust and consistently negative association between CEP and GHG for both developed and developing countries. This result implies that lower GHG (better environmental performance) is strongly associated with better economic performance. In terms of causation, the novel results from the Granger causality tests demonstrate a one-way causation from GHG to both CED and CEP and a one-way causation from CED to CEP. Taken together, these association and causation results add to our knowledge and understanding of the relationships in the CEP, CED and GHG troika.

The over-arching implication for business strategy and government policy is the crucial role of environmental performance, as measured by greenhouse gas emissions. We recognise this finding might surprise those commentators who tend to downplay the importance of environmental factors in corporate economic performance, and we speculate on the reason for the finding in section 5. Nonetheless, given the size and scope of our dataset, as well as variable measurement and analysis, our findings are likely to possess greater generality and robustness than those from previous studies. In addition, the knowledge concerning the causation between the three variables will hopefully inform future academic studies in developing their research models.

The remainder of this paper is organised as follows. In section 2, we review the relevant literature and develop our hypotheses. The model specification is presented in section 3, while section 4 describes the sample and the results. Section 5 provides a discussion of the results and concluding remarks.

2. Literature review and hypotheses development

2.1 The relation between corporate environmental performance and disclosure

The literature provides two contrasting theoretical frameworks in this area with mixed empirical results. First, voluntary disclosure and signalling theories (Verrecchia, 1983; Li *et al.*, 1997) predict a positive association between environmental performance and disclosure, i.e. better performers disclose more environmental information voluntarily in order to distinguish themselves from poorer performers. Al-Tuwaijri *et al.* (2004) and Clarkson *et al.* (2008) find evidence for this view. The second theoretical framework is based on social and political theories (Gray *et al.*, 1995), which view environmental disclosure as a function of

social and political pressures directed particularly towards poorer performers and thus predict a negative association between environmental performance and disclosure. This view often relies on legitimacy theory to explain how poorer performers face more socio-political pressures and have greater incentives to disclose more environmental information voluntarily in order to change perceptions and thereby “legitimise” their activities. Examples of supporting empirical studies include Bewley and Li (2000), Patten (2002), Cho and Patten (2007), and Clarkson *et al.* (2011a).

Other studies, however, find no association between environmental disclosure and performance (e.g., Freedman and Wasley, 1990; Fekrat *et al.*, 1996). One reason for the mixed results is the use of different proxies for environmental performance and disclosure. Delmas and Blass (2010, p. 246-247) note the diversity of corporate environmental performance indicators, which are usually divided into three main categories: (1) environmental impact (toxicity, emissions, energy use etc.); (2) regulatory compliance (non-compliance status, violation fees, number of audits etc.) and (3) organisational processes (environmental accounting, audits, reporting, environmental management system etc.). Even where the proxies for environmental disclosure and performance are related, for example proxies using GHG, studies still report mixed results (e.g., Freedman and Jaggi, 2004; 2011; Kim and Lyon, 2011; Luo and Tang, 2014). Freedman and Jaggi (2004) find firms that emit the most carbon dioxide provide the most extensive disclosures, while Luo and Tang (2014) find that lower emissions are associated with more environmental disclosure. On the other hand, Freedman and Jaggi (2011) find no significant association between GHG disclosures and carbon emissions. Measurement problems also include subjective measures of disclosure which hinder

generalisability and comparability of the results, and samples which are small and insufficiently diversified to provide meaningful inference (Patten, 2002).

Overall, the empirical results have been questioned in terms of both methodological and measurement problems (e.g., Patten, 2002; Clarkson *et al.*, 2008). Early studies often report simple correlations between corporate environmental performance and disclosure without controlling for other factors (e.g., Freedman and Jaggi, 1982; Freedman and Wasley, 1990; Fekrat *et al.*, 1996), while subsequent studies address this deficiency by conducting multiple regression analysis but without controlling for variable endogeneity (e.g., Patten, 2002; Clarkson *et al.*, 2008; Luo and Tang, 2014). Even where structural modelling is used, many studies rely on cross-section data and thus lack a temporal dimension. This limitation on model dynamics may account for the birth of the contrasting theoretical frameworks. For example, if poorer performers disclose more current information which leads to better future performance, both legitimacy and voluntary disclosure theories could lay partial claim to explain this type of behaviour.

Furthermore, there is uncertainty about how environmental disclosure can impact environmental performance, leading to calls for more research in this area. Lewis *et al.* (2014) observe that whilst some scholars maintain that environmental disclosure can lead to performance improvement by raising the legitimacy of environmental issues within the firm or by generating external scrutiny, it is common knowledge that firms sometimes comply symbolically with pressures without making substantive changes to their organisational procedures. In other words, environmental disclosure can be a form of “greenwash” rather than a genuine attempt to improve performance.

Al-Tuwaijri *et al.* (2004) argue that environmental disclosure might affect environmental performance by creating a “lower bound” for investors’ expectations. If a firm’s environmental performance deteriorates (without disclosure) and reduces stock price, then shareholders may have grounds for litigation. The management’s reputation for providing credible disclosures might also suffer. In addition, corporate environmental disclosure can increase awareness about potential environmental risks and opportunities, particularly those associated with climate change, and improve company reputation by adopting a proactive approach to tackling them (Sullivan and Gouldson, 2012).

This view coincides with the management-orientation perspective suggested by Qian and Schaltegger (2017), in which corporate environmental disclosure can be used as a management tool to create organisational pressure and incentives to drive actions and achieve carbon reduction and performance improvement. The authors examine the association between changes in carbon disclosure and subsequent changes in carbon performance for a sample of Global Fortune 500 companies for the period 2008 to 2012. They find that changes in carbon disclosure are positively associated with subsequent changes in carbon performance. The result suggests that if carbon disclosure improves, firms are motivated and capable of using disclosure as an ‘outside-in’ opportunity to create change and improve their carbon performance. The results are based on tests of association rather than causation, however, and a test on the reverse hypothesis (i.e. changes in carbon performance are associated with subsequent changes in carbon disclosure) is precluded within the study remit.

Given the diverse findings in this area, we propose to test the following non-directional null hypothesis:

H1: There is no significant association between corporate environmental disclosure and environmental performance.

2.2 The relation between corporate environmental and economic performance

The central question in the environmental-economic performance literature is whether it pays firms to be good to the environment. Good environmental performance might impact economic performance positively through cost-saving, cost or liability avoidance, revenue generation or being an exemplar for best practice (Murray *et al.*, 2006). Another justification for a positive relationship is that if environmental pollution represents inefficient resource usage then its reduction or elimination will benefit both the environment and the bottom line (Porter and van der Linde, 1995). An early contribution by Friedman (1962), however, emphasises the trade-off between firm profitability and corporate social responsibility. In this view, improving environmental performance is costly and thus detrimental to economic performance, implying a negative relationship between corporate environmental and economic performance. But later studies point to an opposite conclusion justified by the idea of complementarity rather than trade-offs (e.g., Bragdon and Marlin, 1972; Spicer, 1978; Waddock and Graves, 1997). A number of studies, however, find no significant association between the variables (e.g., Rockness *et al.*, 1986; Freedman and Jaggi, 1992). Van Beurden and Gossling (2008) find a positive association between corporate social responsibility and economic performance, a result supported by the findings of Clarkson *et al.* (2011b) among others. A large scale study (Endrikat *et al.*, 2014) conducts a meta-analytic review of 149 studies on the environmental-economic performance relation and reaches broadly the same finding, namely that the relationship is generally positive. Another meta-analytic review (Lu and Taylor, 2016) reaches similar conclusions. A number of studies focusing on greenhouse

gas emissions as the measure of environmental performance conclude that good environmental performance is associated with good economic performance (e.g., Chapple *et al.*, 2013; Matsumura *et al.*, 2014; Clarkson *et al.*, 2015; Baboukardos, 2017), but others still report mixed results (e.g., Misani and Pogutz, 2015; Zhao and Murrell, 2016; Nollet *et al.* 2016).

Overall, the results of these numerous empirical studies are inconclusive. Methodological and measurement problems are typically cited as the culprits. McWilliams and Siegel (2000) highlight the issue of omitted variable bias, whilst Van Beurden and Gossling (2008) point to the inconsistency in variable definitions, the inconsistency in how each concept is measured, and inconsistent research design. Accordingly, we propose the following non-directional null hypothesis:

H2: There is no significant association between greenhouse gas emissions and corporate economic performance.

2.3 The relation between corporate environmental disclosure and economic performance

Both signalling and legitimacy theories have been used to explain how CEP impacts CED, but there is a lack of a clear theoretical framework on how CED impacts CEP. One suggestion from voluntary disclosure theory is that credible environmental disclosure which conveys information over and above what investors already know about firm environmental performance impacts economic performance by facilitating financial performance prediction and/or reducing the cost of capital (Clarkson *et al.*, 2013).

Murray *et al.* (2006) explore whether there is any relationship between social and environmental disclosure and financial market performance for a sample of 100 large UK companies over the period 1989 to 1997. Based on a total of 660 instances of disclosure they

find no association between share returns and disclosure. However, their results show that companies with consistently higher (lower) returns are likely to have consistently higher (lower) levels of total and voluntary social and environmental disclosure in their annual reports. The study also finds that although the relationship for the sample period is strong, the cross-section (i.e. year on year) results are insignificant and unstable, suggesting that a panel data analysis would generate more consistent results. Lorraine *et al.* (2004) examine the effect of environmental news on share prices using a cross-sectional analysis of a small UK sample of 32 companies (9 with good news and 23 with bad news). The results provide limited evidence of a lagged market reaction to bad environmental news (i.e. fines due to breaches of regulations). Jacobs *et al.* (2010) examine market reaction to 780 environmental performance announcements for a sample of 340 US companies between the periods 2004 to 2006 and find that the market is selective in its reaction to different types of environmental announcements. For example, while announcements of philanthropic gifts for environmental causes and ISO 14001 certifications are associated with significant positive market reaction, voluntary emission reductions are associated with significant negative market reaction.

An event study conducted by Gupta and Goldar (2005) to investigate the impact of environmental rating announcements on the stock prices of 50 large Indian firms for the years 1999, 2001 and 2002 finds that the announcement of weak environmental performance was associated with negative abnormal returns of up to 30 percent. Freedman and Patten (2004) examine the impact of both environmental performance, measured by the Toxic Release Inventory (TRI), and environmental disclosure on market performance using a cross-sectional analysis of 112 US firms. Their purpose was to study market reaction to the unexpected proposal by President George Bush in June 1989 for revisions to the Clean Air Act and to

identify the impacts of TRI information and 10-K report environmental disclosures. Their results show a negative market reaction to poor environmental performance and a positive reaction to environmental disclosure.

Some studies examine the association between CED and CEP after controlling for environmental performance (e.g., Freedman and Patten, 2004; Clarkson *et al.*, 2013; Plumlee *et al.*, 2015) and generally document a positive association between CED and CEP. For example, based on a sample of 474 US firms over a six-year period (2000-2005), Plumlee *et al.* (2015) examine the value relevance of environmental disclosure: their results suggest that voluntary environmental disclosure is associated with firm value through cash flow and cost of equity components, whilst both the type and nature of disclosures are informative in predicting firm value.

In spite of this large body of empirical work, the results are far from conclusive and difficult to generalise because of the variety of metrics used for both the environmental disclosure and economic performance variables. Consequently, we again prefer to frame our research hypothesis in terms of a non-directional null hypothesis:

H3: There is no significant association between corporate environmental disclosure and economic performance.

3. Research model

In this section, the associations between CEP, CED and GHG are examined by means of structural equations controlling for potential endogeneity and employing a range of control variables. The direction of causation between the variables is examined by means of Granger causality tests in the next section.

Management strategy is fundamental in determining what a firm does and how it performs, but it is difficult to measure. In a survey of US firms, Ullman (1985) argued that management strategy (in its widest sense) co-determines economic performance, environmental performance and disclosure, and that the omission of this variable from the study methodologies caused an endogeneity problem. Failure to allow for this endogeneity results in biased and inconsistent estimators if ordinary (OLS) or generalised least squares (GLS) single-equation estimation is used. In the absence of a suitable metric for management strategy, the endogeneity problem can be addressed by system estimation.

We develop a simultaneous three-equation model within which to conduct system estimation. To the best of the authors' knowledge, the only other study to adopt this methodology in this area appears to be that of Al-Tuwaijri *et al.* (2004), which uses a cross-sectional sample of 198 large US firms and compares the OLS estimates with two- and three-stage least squares estimates. But a self-constructed disclosure index is used to measure CED, and the authors acknowledge that their measure of environmental performance (the ratio of toxic waste recycled to total toxic waste generated) does not capture the relative toxicity of the waste being recycled. The current study methodology features important differences that continue to further our understanding of the CEP, CED and GHG relations. It uses both time series and cross-section data with a greater number of observations and a wider range of firm-level and country-level control variables, as well as more general measures of environmental performance and disclosure. In particular, the presence of time series data enables the use of Granger causality testing. The statistical power of both studies is compared in section 4.3.

Environmental disclosure is generally made some months after greenhouse gas emissions have occurred and after the financial year-end, implying that environmental

disclosure cannot have a contemporaneous association with economic or environmental performance. It is possible, however, that environmental disclosure has a lagged association with GHG and CEP, and there is empirical evidence for this link from other studies (e.g., Lorraine *et al.*, 2004). This possibility is allowed for in the model specification, although it is assumed that economic and environmental performance can have a contemporaneous association with environmental disclosure. We propose the following model specification (cross-section and time identifiers are suppressed for simplicity) to test the research hypotheses developed in the previous section:

$$(1) CEP = \alpha_0 + \alpha_1 GHG + \alpha_2 CED_{(-1)} + \alpha_3 SIZE + \alpha_4 BSZ + \alpha_5 CEO + \alpha_6 WOB + \alpha_7 GDP + \alpha_8 CCGP + \alpha_9 LEV + \alpha_{10} CAP + \varepsilon_1$$

$$(2) GHG = \beta_0 + \beta_1 CEP + \beta_2 CED_{(-1)} + \beta_3 SIZE + \beta_4 BSZ + \beta_5 CEO + \beta_6 WOB + \beta_7 GDP + \beta_8 CCGP + \beta_9 ENG + \beta_{10} IND + \varepsilon_2$$

$$(3) CED = \gamma_0 + \gamma_1 CEP + \gamma_2 GHG + \gamma_3 SIZE + \gamma_4 BSZ + \gamma_5 CEO + \gamma_6 WOB + \gamma_7 GDP + \gamma_8 CCGP + \gamma_9 CHP + \gamma_{10} KYO + \varepsilon_3$$

3.1 Endogenous variables

CEP = Corporate economic performance measured by Tobin's Q ratio ((market capitalisation + total liabilities + preferred equity + minority interest) / total assets). Tobin's Q ratio is used as a proxy for firm economic performance in numerous related studies (e.g., King and Lenox, 2001; Misani and Pogutz, 2015; Zhao and Murrell, 2016), with a higher ratio indicating a better economic performance. In general, studies have used either accounting-based measures (such as return on assets, return on equity and leverage) or market-based measures (such as Tobin's Q ratio, firm value, stock returns) to proxy for firm economic

performance. While accounting-based measures focus on the past performance of a firm (e.g., Malarvizhi and Matta, 2016; Lee et al., 2016; Qiu *et al.*, 2016; Czerny and Letmathe, 2017), market-based measures (e.g., Clarkson *et al.*, 2013; Plumlee *et al.*, 2015; Yadav *et al.*, 2016) reflect the market's perception of its future economic performance. Accounting-based measures focus on the efficiency of internal decision making in the use of firm resources, but can be subject to management manipulation. Market-based measures are less prone to differences in accounting procedures and management manipulation, but assume market efficiency where full market efficiency is at best an unrealistic case (McGuire *et al.*, 1988). To allow for these considerations, we use a market-based measure in the main analysis and check the robustness of our results by replacing the market-based measure with accounting-based measures, i.e. return on assets and return on equity.

GHG = Environmental performance measured by greenhouse gas emissions (millions of metric tonnes) or, if unavailable, by carbon dioxide (CO₂) emissions. This allows comparability across companies that report either GHG or CO₂ emissions, but not both. The difference between the two measures is small. GHG or CO₂ emissions have been used in a number of studies to proxy for environmental performance (e.g., Freedman and Jaggi, 2011; Kim and Lyon; 2011; Aperies *et al.*, 2013; Luo and Tang; 2014). GHG data is available for many companies and provides a consistent and general measure for environmental performance across companies, countries and time.

CED = Environmental disclosure score, which is a proprietary Bloomberg score based on the extent of a company's environmental disclosure. It is a subset of the Bloomberg ESG disclosure score, which quantifies a company's transparency in reporting environmental, social and governance data, and has been used in a number of recent related academic studies (e.g.,

Nollet *et al.*, 2016; Qiu *et al.*, 2016; Bernardi and Stark, 2016). The environmental disclosure score is weighted to emphasise the most commonly disclosed fields such as greenhouse gas emissions and normalised to range from zero for companies that do not disclose environmental information to 100 for those which disclose every data point collected. In addition, Bloomberg accounts for industry-specific disclosures by normalising the final score based only on a selected set of fields applicable to the industry type. For example, “Total Power Generated” is counted into the disclosure score of utility companies only.

We choose this proxy for environmental disclosure because the environmental disclosure is made on a voluntary basis and hence is subject to management discretion. This contrasts with the Carbon Disclosure Leadership Index (CDLI) provided by the Carbon Disclosure Project, which is perceived as solicited disclosure that companies provide in response to pressure from institutional investors (Van der Laan, 2009), thereby limiting management discretion over what, where, how and when to disclose environmental information.

The Bloomberg measure covers a wide range of environmental information such as greenhouse gas emissions, total energy consumption, total water use, total waste, number of spills, environmental initiatives, and environmental policies. Thus, it captures the incremental impact of environmental disclosure over and above what investors already know about firm environmental performance using GHG or CO₂ emissions (Clarkson *et al.*, 2013). Furthermore, as previously noted, the proxy is comparable across industries and countries, in contrast to self-constructed methods such as content analysis and disclosure indexes.

3.2 Predetermined variables

Firm-level control variables

These consist of firm size (*SIZE*), leverage (*LEV*), and capital expenditure (*CAP*) (e.g., Walls *et al.*, 2012; Misani and Pogutz, 2015; Nollet *et al.*, 2016; Zhao and Murrell, 2016). *SIZE* is measured by turnover (US\$ millions) less an adjustment for items such as returns and discounts. *LEV* is financial leverage measured as net debt to equity as a proxy for financial risk. *CAP* is capital expenditure as a proxy for firm efficiency in the deployment of its assets. It reflects the total amount the company spent on the purchase of tangible fixed assets to maintain production and generate revenue (Qian and Schaltegger, 2017).

Turning to the expected coefficient signs, the *SIZE* effect in equation (1) is ambiguous because the effect of firm size on economic performance depends partly on the nature and extent of scale economies available to the firm. The *SIZE* effect in equation (2), however, is less ambiguous: after controlling for industry type (*IND*) we expect larger firms to emit more greenhouse gases. The *SIZE* effect in equation (3) is predicted to be positive, because larger firms are expected to disclose more voluntary information compared to smaller firms (e.g., Al-Tuwaijri *et al.*, 2004; Freedman and Jaggi, 2011; Luo and Tang, 2014). *CAP* is expected to be positively associated with *CEP* (King and Lenox, 2001; Walls *et al.*, 2012) and *LEV* to be negatively related (Nollet *et al.* 2016; Misani and Pogutz, 2015).

Three proxies are included for board characteristics, namely board size (*BSZ*), chief executive officer duality (*CEO*) and gender diversity (*WBO*). *BSZ* is board size measured by the number of full time directors on the company's board. *CEO* is a dummy variable which equals one if the company's chief executive officer is also the chairman of the board and zero if the two roles are separate. *WBO* is the proportion of women on the board of directors. Board

characteristics have been related to firm performance and disclosure practice in prior studies with mixed results (e.g., Jensen, 1993; Freedman and Jaggi, 2011; Walls *et al.*, 2012; Liao *et al.*, 2015; Lewis *et al.*, 2014; Li *et al.*, 2017), so we do not predict the coefficient sign for these variables.

Other firm-level control variables are the existence of a climate change policy (CHP), the existence of an energy efficiency policy (ENG), and industry type (IND) (e.g., Madsen and Ulhøi, 2016; Misani and Pogutz, 2015; Lewis *et al.*, 2014; Walls *et al.*, 2012). *CHP* equals one if the firm has a climate change policy describing its commitment to reduce GHG through its ongoing operations and/or the use of its products and services and zero otherwise. Examples of CHP include efforts to reduce GHG, improve energy efficiency, derive energy from cleaner fuel sources, and investment in product development to reduce emissions or energy consumed in the use of the company's products. We expect companies with a CHP to disclose more environmental information compared to companies without such a policy. *ENG* equals one if the company has reported implementing initiatives to make its energy use more efficient and zero if the company has not explicitly disclosed any such efforts in its annual or company responsibility reports. The impact of ENG on GHG in equation (2) is expected to be negative, since greater energy efficiency should reduce greenhouse gas emissions. *IND* equals one if the firm is in the industrial, energy or utility sectors according to the Bloomberg Industry Classification System (BICS) and zero otherwise. Companies in these sectors are expected to have higher GHG or CO₂ emissions, *ceteris paribus*.

Country-level control variables

We include three variables to control for country differences: GDP, KYO and CCGP (e.g., Apergis *et al.*, 2013; Kim and Lyon, 2011). GDP is the gross domestic product per capita

(US\$ current prices) in the firm's country of origin, KYO is a dummy variable which equals one if the Kyoto Protocol is in force in the firm's country of origin and zero otherwise, and CCGP is the first principal component of corporate governance indicators at country level. This measure is derived from six corporate governance indicators: control of corruption, government effectiveness, political stability and absence of violence/terrorism, regulatory quality, rule of law, and voice and accountability. These indicators range from -2.5 to +2.5 and are highly correlated. We apply principal component analysis to these indicators (results not tabulated) and use the first principal component (CCGP) in the subsequent analysis. This CCGP component explains 87 percent of the variation in the original six corporate governance indicators.

Our study period spans the financial crash starting in 2007. The GDP variable acts as a control for the differential country shocks experienced in the wake of the crash as well as a measure of economic development. Higher GDP per capita (and CCGP) are expected to be associated with more efficient capital, currency and product markets as well as a better economic performance and information environment. Accordingly, we predict a positive relationship between both GDP and CCGP with CEP and CED in equations (1) and (3) respectively. In equation (2) we expect a higher GDP to be associated with higher levels of economic activity and higher greenhouse gas emissions, implying a positive relationship, although there is a possibility that a higher standard of living induces greater public and government pressure to reduce the firm's environmental footprint, implying a negative relationship. A similar argument applies to CCGP. In equation (3), we expect companies originating in countries signed up to the Kyoto Protocol to disclose more in response to

government regulation and/or public pressure (Kim and Lyon, 2011). Table 1 provides a summary of the variables used in the model specification.

<INSERT TABLE 1 HERE>

4. Sample and results

4.1 Sample

Company-level data for this study are collected from the Bloomberg database, country-level data on GDP and corporate governance are from the World Bank. The date of enforcement of the Kyoto Protocol per country is collected from the United Nations website.

Our initial sample comprised all firms having climate change information in the Bloomberg database. This consisted of 2,094 firms worldwide for the period 2006 to 2014 with a maximum 18,846 firm-year observations, but the size of our final sample depends on the availability of data for each variable included in the model specification. This yields a total of 1,607 firms with 9,120 firm-year observations from 45 countries worldwide, comprising 1,392 firms from developed countries (8,121 firm-year observations) and 215 firms from developing countries (999 firm-year observations). The United States, Japan and Britain have the highest number of observations, while Malta, Mauritius and United Arab Emirates have the lowest.

4.2 Descriptive analysis

Table 2 provides descriptive statistics and Spearman correlations for the common sample of 9,120 firm-year observations. The average company has a Tobin's Q ratio (CEP) of 1.57, greenhouse gas emissions (GHG) of 4.82 million metric tonnes, an environmental disclosure score (CED) of 35.55 points, a sales revenue (SIZE) of 15,365.10 million USD, a

financial leverage (LEV) of 82 percent and originates in a country with a gross domestic product per capita (GDP) of 43,646.77 USD. The average company spends over 1,000 million USD on capital expenditure (CAP).

About 89 percent of companies have reported introducing an energy efficiency policy (ENG) to reduce their environmental footprint, and 32 percent are in the industrial, energy and utility sectors (IND). 63 percent have climate change policies (CHP) to reduce GHG and 80 percent originate from countries where the Kyoto Protocol is in force (KYO). The average board size (BSZ) is about 11 persons, the average percentage of women on the board of directors (WOB) is 13.27 percent, and 27 percent of companies have their company's chief executive officer (CEO) as the chairman of the board. Finally, the first principal component of corporate governance at country level (CCGP) has an average score of 0.13.

<INSERT TABLE 2 HERE>

We comment briefly on some of the Spearman correlations in Table 2. The pairwise correlations between CEP, CED and GHG are all significant at the one percent level (two-tailed). The correlations between CEP and each of GHG and CED are negative, indicating that good environmental performance (lower GHG) and less environmental disclosure are associated with better economic performance. The positive correlation between GHG and CED (poor environmental performance is correlated with more environmental disclosure) is consistent with the legitimacy theory referred to in the literature review section.

Higher investment in tangible assets (CAP) is significantly and positively correlated with GHG (higher investment is associated with poorer environmental performance) and CED (more investment is associated with more environmental disclosure), but significantly and

negatively correlated with CEP. Interestingly, companies with initiatives to reduce greenhouse gas emissions such as ENG and CHP have higher greenhouse gas emissions (correlations 0.121 and 0.250 respectively), and disclose more environmental information (correlations 0.366 and 0.454 respectively), results which again are consistent with legitimacy theory. They also have a significant but negative correlation with economic performance (correlations -0.060 and -0.139 respectively). Firms from countries where the Kyoto Protocol is in force (KYO) have lower greenhouse gas emissions (good environmental performance) and higher environmental disclosure but a worse economic performance.

These results should be treated with caution since they focus only on pairwise correlations without considering the influence of other variables. The estimated coefficients from an appropriately specified structural model may yield different results and conclusions.

4.3 Estimation procedure and results

Our main interest is in the full sample results, but we also consider the possibility that stages of economic development play a role in the CEP, CED and GHG relationships. Accordingly, we disaggregate between developed and developing countries using the United Nations classification and estimate equations (1) to (3) on the full, developed and developing country samples. Amongst other factors, the disaggregation may help control for inter-country technology differences (e.g., Czerny and Letmathe, 2017), which is an omitted variable in our model because of the lack of an appropriate metric.

In response to Ullman's (1985) critique, we test for endogeneity of the right-hand side variables CEP and GHG. Endogeneity, if it exists, implies that single equation OLS and GLS estimators are biased and inconsistent, i.e. they do not converge to their true population values

no matter how large the sample size is. A Hausman test (results not tabulated) indicates the existence of endogeneity between CEP and GHG. Accordingly, we conduct system estimation of equations (1) to (3).

Three system estimation methods are considered: three-stage least squares (3SLS), full information maximum likelihood (FIML) and the generalised method of moments (GMM). We choose between them by comparing the standard errors of the regressions. Using the R-squared or adjusted R-squared in system estimation is not recommended because the statistic is unbounded below zero and often produces negative values. In all three samples (full, developed and developing countries) FIML has the highest standard error of the regression, and in two (full and developed countries) GMM has the lowest. Accordingly, we use GMM in the full and developed country samples. GMM does not compute for developing countries because of a near singular matrix (possibly due to the relatively small number of observations), thus we use 3SLS instead.

Table 3 shows the system estimation results. In total there are 99 estimated coefficients (33 per sample) of which a high number (80) are statistically significant, a significance rate of just over 80 percent. There are 66 coefficients significant at the 1 percent level, 10 at the 5 percent level, and 4 at the 10 percent level. As an indicator of statistical scope and performance, we compare our full sample results with the system estimation results of Al-Tuwaijri *et al.* (2004, Table 3). In this latter study there are 19 estimated coefficients of which 12 are significant, 8 at the 1 percent level. Our full sample has 33 estimated coefficients of which 28 are significant, 25 at the 1 percent level. We now comment on each equation in turn.

<INSERT TABLE 3 HERE>

Equation One: dependent variable CEP (corporate economic performance)

The key result is the negative and highly significant coefficient on GHG in all three samples. After controlling for prior environmental disclosure, financial leverage, capital spending, firm size, board characteristics, GDP per capita, and corporate governance at country level, we find that the lower the firm's GHG, the better its economic performance and vice versa. In other words, good environmental performance is associated with good economic performance across a wide range of companies, countries and time. The negative coefficient is also consistent with the negative correlation in Table 2.

The coefficient on CED(-1) is positive and significant in the full and developing country samples, consistent with results from Freedman and Patten (2004), Clarkson *et al.* (2013), and Plumlee *et al.* (2015), but negative and significant for developed countries, implying that greater prior environmental disclosure is associated with a worse current economic performance (Shane and Spicer, 1983; Stevens, 1984; Richardson and Welker, 2001). Possible explanations for the negative association are that poor environmental performers who disclose this fact are subsequently punished by financial markets or, alternatively, firms can hide "bad news" by disclosing less environmental information and artificially boosting their bottom line.

The negative and highly significant SIZE coefficients for the full and developed country samples suggest that the economic performance of larger firms may be adversely affected by the presence of diseconomies of scale, consistent with results from Misani and Pogutz (2015) and Nollet *et al.* (2016). The positive SIZE coefficient for the developing countries sample is not necessarily a counterfactual, since these countries might have smaller firms that are less prone to diseconomies of scale. All the coefficients on CAP and LEV are significant. The

positive sign on CAP (in contrast to the negative correlation in Table 2) and negative sign on LEV implies that better economic performance is associated with higher capital spending and lower financial leverage, as expected, although the CAP coefficient is negative for developing countries.

The association between CEP and board size (BSZ) is negative and highly significant for the full and developing country samples, but insignificant for developed countries. The association between CEP and CEO duality (CEO) is positive and highly significant for developed countries, but insignificant elsewhere. The significant results are consistent with those from Walls *et al.* (2012), where smaller board size and CEO duality are associated with better economic performance. Having more women on the board of directors (WOB) is positively associated with economic performance in all three samples, highly significant in the full and developed country samples, but insignificant for developing countries. Economic performance is positively and significantly associated with GDP (as expected) in the full and developed country samples, but negatively for developing countries. Corporate governance at country level (CCGP) is negatively associated with CEP in the full sample (an unexpected result), insignificant in the developed countries sample, and positive in the developing countries sample.

Equation Two: dependent variable GHG (environmental performance)

There is a negative coefficient on CEP in all three samples, consistent with the negative coefficients on GHG in equation (1). In terms of significance, however, the situation is less clear. The coefficient on CEP is insignificant in the full sample, and significant only at the 10 percent level in the sub-samples. Whilst GHG is a highly significant explanatory variable for

CEP in all three samples, the reverse is not the case. This is an important corroborative result, because it reinforces the findings of the causality testing in section 4.4.

The positive and highly significant coefficient on CED(-1) in all three samples implies that more prior environmental disclosure is associated with more GHG (bad environmental performance), a result inconsistent with the “lower bound” model of Al-Tuwaijri *et al.* (2004), but consistent with the gaming model of Li *et al.* (1997) where good environmental performers choose to disclose less through fear of litigation if greater disclosure might result in reputational damage. Alternatively, firms may feel it necessary or prudent to signal the possibility of poor performance to investors, thereby reducing the possibility of shareholder litigation if firm value falls. The coefficients on SIZE and IND are positive and highly significant across the three samples, consistent with Walls *et al.* (2012) and implying that larger firms and firms from the energy, industry and utility sectors produce more GHG, *ceteris paribus*. As expected, energy efficiency policy (ENG) is significantly and negatively associated with GHG in the full sample, although insignificant in the developed and developing country samples.

Walls *et al.* (2012) and Lewis *et al.* (2014) find that larger boards and CEO duality are associated with more GHG. Our results for CEO support this latter finding: the CEO coefficient is positive in all three samples, and significant in two. The results for BSZ are mixed, since the coefficient is insignificant in two samples and has a sign change. It is a similar story for WOB, which is negatively (positively) associated with GHG in developed (developing) countries, but has no significance in the full sample. The GDP and CCGP coefficients are significant in all samples but exhibit sign reversal between developed and developing countries. The GDP (CCGP) signs are positive (negative) in the full and developed country samples but negative (positive) for developing countries. One explanation might be that poorer countries starting

with “dirty” production technologies are able to substitute cleaner technologies as GDP increases, an opportunity less available to developed countries. The positive CCGP sign for developing countries is more problematic because it implies that firms in poorer countries with improving country level corporate governance emit more GHG, even after controlling for GDP.

Equation Three: dependent variable CED (corporate environmental disclosure)

The association between CED and each of CEP and GHG is highly significant in all samples, but there is sign reversal. The coefficient sign is positive for the full and developing country samples, implying that better economic and worse environmental performance are each associated with more environmental disclosure, but negative for developed countries. The negative sign implies that worse economic and better environmental performance are each associated with more disclosure. These mixed results reflect the contrasting theoretical perspectives noted earlier in relation to environmental disclosure.

The SIZE coefficients are positive and highly significant, as expected, for the full and developed country samples, but negative and insignificant for developing countries. The CHP coefficients are positive and highly significant, as expected, in all three samples. The association between KYO and CED is positive and highly significant for the full sample, implying that companies originating in countries where the Kyoto Protocol is in force disclose more than non-signatories, a result consistent with Kim and Lyon (2011), although the coefficients in the sub-samples are insignificant.

The coefficients on BSZ are positive and highly significant for all samples, implying that larger boards have higher disclosure. The CEO coefficients are positive and highly significant in the full and developed country samples, although negative and insignificant for

developing countries. The coefficient on WOB is highly significant in the three samples, but positive for developed countries and negative and significant in the full and developing country samples. As expected, there is a significant and positive association between environmental disclosure and GDP per capita in all samples. Finally, corporate governance mechanisms at country level (CCGP) are negatively associated with CED in all samples, significant for both developed and developing countries but insignificant for the full sample. The negative coefficient implies that corporate environmental disclosure increases as corporate governance at country-level worsens, an unexpected result but one which may be explicable in terms of legitimacy theory, i.e. companies in a country with deteriorating governance might disclose more in order to legitimise a poor environmental performance to domestic and international environmental agencies.

4.4 Stationarity and Granger causality tests

Standard regression analysis demonstrates the association between variables, but not causality (Tabachnick and Fidell, 2014). The issue of testing for causality is complex, but a widely used method is that of Granger (1969). Some argue that the test is “quasi-causal” and hence prefer the term “Granger causation”, a practice we follow in the subsequent analysis.

Applying the Granger (1969) approach to the question of whether CEP, for example, causes GHG is to examine whether the current value of GHG can be explained by its past values and then to examine whether adding lagged values of CEP improves the explanation. The regressions are conducted within a vector autoregressive (VAR) framework. The test is strictly temporal in nature, relying on the fact that the past can be used to predict the future but not vice versa. We distinguish these causation tests from our earlier estimations of equations (1) to (3) by continuing to refer to the latter as tests of association. More generally, to test

whether “X Granger-causes Y”, an unrestricted regression including lagged values of Y and X is compared to a restricted regression (null hypothesis) including only lagged values of Y. For a VAR(2) model we have:

$$Y_t = a_0 + a_1 Y_{t-1} + a_2 Y_{t-2} + b_1 X_{t-1} + b_2 X_{t-2} + e_t \quad (\text{Unrestricted regression})$$

$$Y_t = a_0 + a_1 Y_{t-1} + a_2 Y_{t-2} + e_t \quad (\text{Restricted regression})$$

The F-statistic for the F-test is formulated as:

$$F = \frac{\frac{RSS_R - RSS_u}{p}}{\frac{RSS_u}{T - k}} \sim F(p, T - k)$$

Where RSS is the residual sum of squares from the restricted (R) and unrestricted (U) regressions, p is the number of lagged restrictions, T is the sample size and k is the number of estimated parameters. The null hypothesis is that the *b* coefficients are zero. If the calculated F statistic is greater than the critical F statistic, we reject the null and conclude that X Granger-causes Y. This procedure can be repeated for testing whether Y Granger-causes X. Rejection of both null hypotheses implies bilateral causation.

The Granger causality test assumes that the variables in question are stationary, i.e. they do not contain a unit root. We test for the presence of a unit root using panel tests that have higher power than unit root tests based on individual time series. The Levin *et al.* (2002) test assumes a common autoregressive structure (common root) for all series, while the Im *et al.* (2003) test allows for different autoregressive coefficients (individual root). The test results for CEP, CED and GHG (not tabulated) show that in all cases the null hypothesis that the series

contains a unit root is rejected at the 1 percent significance level, implying strong evidence for the stationarity of these variables. We use a block exogeneity Wald test which enables multiple explanatory variables to be considered as causal candidates in the VAR. The test also handles the possibility that all lagged explanatory variable coefficients are jointly equal to zero. Our panel data spans nine annual observations (2006 to 2014), a length of time we believe is sufficient to conduct meaningful tests for Granger causality. But the test has drawbacks: the results are sensitive to the lag order employed in the VARs, and higher lag orders substantially reduce the number of observations. To deal with this problem, we conduct sequential tests using one, two, three and four lags and note the most consistent decision outcomes. The tests with one and two lags produce exactly the same decision outcomes for all cases, so we present the results of the tests using two lags in Table 4.

<INSERT TABLE 4 HERE>

The decision outcomes for the full and developed country samples are identical, so we report on the differences between the developed and developing country results. For developed countries, GHG Granger-causes CEP but not vice versa, CED Granger-causes CEP but not vice versa, and GHG Granger-causes CED (in this case at the 10 percent significance level) but not vice versa. The decision outcomes for the developing countries differ in the following respects: GHG does not Granger-cause CEP, and CED does not Granger-cause CEP. GHG, however, still Granger-causes CED, the only causality in this sample.

This one-way causation appears to be a distinctive result in the causation literature, although this literature is much less extensive than that relating to tests of association in cross-sectional studies. The meta-analytic review by Endrikat *et al.* (2014) concludes that, based on

the studies containing causation analysis, there is causation from corporate environmental performance to economic performance and limited evidence of reverse causation. In terms of corporate environmental disclosure and economic performance, Qiu *et al.* (2016) find that although environmental disclosure does not Granger-cause economic performance, there is some evidence of reverse causation. It should be noted, however, that our results are based on nine (consecutive) time periods whereas other studies generally have fewer time periods and occasionally use non-consecutive time periods. Exceptions are the studies by King and Lenox (2001) and Clarkson *et al.* (2011b), although the former considers environmental performance and economic performance but not environmental disclosure, whilst the latter analyses environmental performance and economic performance over the period 1990 to 2003 but the three-way relationship between economic performance, environmental performance and disclosure for a single time period only (year 2003).

Finally, we conduct a number of sequential robustness checks on the model data and specification (results not tabulated). Variables with extreme values at the 5th and 95th percentile are winsorized, and we replace our proxy for economic performance (Tobin's Q ratio) with two alternative proxies, namely return on assets (ROA) and return on equity (ROE). The results are qualitatively similar to our original results, apart from the association between environmental disclosure and economic performance in equation (3), where there is a positive association between CED and each of Tobin's Q ratio and ROA but a negative association between CED and ROE. We also apply robustness checks to the causality tests and find that the results are qualitatively similar (results not tabulated). Overall, we conclude that our model is reasonably robust to these checks.

5. Discussion and conclusions

Our model specification and estimation of the associations between CEP, CED and GHG yield a high proportion of significant coefficients, with two-thirds highly significant (i.e. at the 1 percent level). A compelling result is the role of environmental performance, measured by greenhouse gas emissions, as a highly significant explanatory variable for corporate economic performance: GHG is negatively and highly significantly related to CEP in equation (1) in all samples, implying that good environmental performance is strongly associated with good economic performance. But the reverse case is less compelling: CEP is a negative but insignificant explanatory variable for GHG in equation (2) in the full sample, and only significant at the 10 percent level in the sub-samples. An echo of this result occurs in the causation tests of Table 4, where GHG Granger-causes CEP (in the full and developed country samples) but CEP does not Granger-cause GHG in any samples. Overall, we conclude that in the GHG/CEP relationship, GHG is the dominant partner.

Our main interest is in the full sample results, where 28 of the 33 estimated coefficients are significant; a significance rate of 85 percent. Of the 28 significant coefficients, 25 are highly significant. Where a firm prediction is made about the coefficient sign of the control variables, this prediction is usually accurate. For example, the variables SIZE, GDP, LEV and CAP have the expected signs, as do the dummy variables ENG, IND, CHP and KYO, and in nearly every case these coefficients are highly significant (with the exception of ENG which is significant at the 5 percent level). Only in the case of the association between CCGP and CEP is there a significant but unexpected coefficient sign.

We do not possess a control variable for inter-country technology differences, so we disaggregate between developed and developing countries as a robustness check. In general,

the system estimation results for these sub-samples exhibit mixed correspondence in terms of coefficient sign and significance. For example, whilst LEV, IND and CHP are significant and have the expected sign in all three samples, the board variables BSZ, CEO and WOB exhibit less consistency (although there is a positive and significant association between the number of women on the board of directors and economic performance in the full and developed country samples). KYO is positive and significant in the full sample yet negative and insignificant in both sub-samples. One explanation for the mixed correspondence is that these distinct types of economy are structurally different and behave differently to the same stimulus, so pooling them together masks significant differences between them. Another explanation may be the small sample size of developing relative to developed countries.

The split between developed and developing countries produces interesting results for the SIZE and GDP variables. SIZE and GHG are, as expected, positively and significantly associated in all the samples. The bigger the firm, the greater its GHG, *ceteris paribus*. There is a sign reversal for SIZE in relation to CEP, but this does not necessarily imply a lack of robustness: the negative sign for developed countries might occur via diseconomies of scale, in contrast to the positive sign (economies of scale) for developing countries. Another interesting sign reversal is that GDP and GHG are positively and negatively related in developed and developing countries respectively, suggesting that developing countries might be able to substitute clean for dirty technologies in the earlier stages of their growth cycle, an opportunity less available to more mature developed countries. The same sign reversal occurs for GDP and CEP, possibly because of a threshold effect whereby good economic performance depends on reaching a certain level of economic development.

The existence of a time lag between disclosure and environmental/economic performance suggests that prior rather than current disclosure should feature as the explanatory variable in model specification, and this is the basis for including CED(-1) in equations (1) and (2). But understanding the impact of prior environmental disclosure on CEP and GHG is problematic for a number of reasons, including the role played by company expectations and market reaction, the limited literature on prior disclosure (many studies investigate current rather than prior disclosure) and the different measures used for the disclosure variable. Indeed, the plethora of variable measures and the consequent non-comparability of studies is a problem plaguing research using environmental disclosure and performance variables, and one suggestion for future research is to achieve a greater standardisation of the variable metrics. Our measures of environmental disclosure and performance have the advantage that they are collected on a consistent basis across companies in many different countries and over time.

There is a highly significant and positive association between CED(-1) and GHG in all samples, i.e. more prior environmental disclosure is associated with more current GHG, consistent with the gaming model of Li *et al.* (1997). The association between prior environmental disclosure and current economic performance is also highly significant in all samples, but positive in the full and developing country samples and negative for developed countries. This sign indeterminacy reflects the findings of the limited research literature on the CEP/CED(-1) relationship: a positive coefficient sign is found in Clarkson *et al.* (2013), for example, but a negative and insignificant sign in Al-Tuwaijri *et al.* (2004). In view of these mixed results, and the sparseness of the literature, calls for further research on the impact of prior environmental disclosure appear justified.

There are also mixed results in the sub-samples for the association between CED in equation (3) and CEP and GHG. For developed countries CEP and GHG are negatively and significantly related to CED, but positively and significantly related in developing countries. These mixed results replicate those found in the research literature more generally, and to reiterate the point made in the preceding paragraph we suggest that one explanation could be the gaps in our understanding of the process and effects of environmental disclosure, particularly in developing countries. More research is needed to understand how the interactions between CEP, CED and GHG change at different stages of the economic growth cycle.

A feature of the current study is its response to research calls to examine the direction of causation between CEP, CED and GHG and, by implication, whether prior environmental disclosure impacts current environmental performance. We find instances of a one-way causality but, in contrast to some studies, none of bi-directional causality. The role of environmental performance is central in these results. Our finding of a one-way Granger causation from GHG to CED is robust for all samples, and GHG Granger-causes CEP in the full and developed country samples. CED also has a one-way causal influence on CEP in the full and developed country samples which, by virtue of the nature of the Granger causality test, we construe as further evidence of the significant association between $CED(-1)$ and CEP in the system estimation results. CEP, on the other hand, has no causal influence on either GHG or CED, results which hold in all samples. We also document non-causation from either CEP or CED or both to GHG. This result is robust for all samples and calls for further research to explore the factors causing variations in GHG.

Taken together, these association and causation results highlight the importance of environmental performance (measured by GHG) and, to a lesser extent, environmental disclosure, over economic performance. Some might find this a surprising result, and it is natural to consider the wider socio-economic factors which might explain it. The authors speculate that increasing domestic and international concern for the environment, evidenced particularly by the adoption of the Kyoto Protocol in 1997, has created a global market place in which business strategy, especially amongst larger companies which are more exposed to the glare of the environmental spotlight, must pay at least as much attention to environmental as economic performance. Would the same result occur in a similar study conducted at any point in the latter half of the twentieth century? Probably not, because economic priorities dominated concerns over the environment. The backdrop to the twenty-first century is very different, and business strategy has generally adapted to it. We believe this is the change which accounts for our finding, although there is plenty of scope for further speculation.

A limitation of our dataset is the small number of time periods in relation to cross-sections. Whilst this limitation is a common feature of panel data, additional time periods would be welcome. These will accrue naturally with the passage of time, and represent an important avenue for future research. More generally, whilst there has been no shortage of cross-sectional studies on the relations between economic performance and environmental performance and disclosure, future research can focus on extending the temporal aspects of the analysis. This would be especially useful for understanding model dynamics, particularly the role of current and prior environmental disclosure. Lack of temporal data notwithstanding, to the best of the authors' knowledge the current study has more time periods than others in this

area. It should be noted, however, that the study is potentially geared towards larger firms (average annual sales of \$15 billion).

To conclude, the current study uses a relatively large panel dataset, together with greenhouse gas emissions as the environmental performance metric and a more objective measure of environmental disclosure, to estimate a simultaneous equation system across many countries as well as companies, thus providing greater generality and statistical precision in the estimation results. The model contains a wide range of firm and country-level control variables and passes a number of robustness checks in relation to tests of association and causation, although there is a need for further research in the context of the split between developed and developing countries. In particular, the results demonstrate strong evidence of a one-way causation from environmental performance and disclosure to economic performance, but no evidence of reverse causation. They also show strong evidence of a one-way causation from environmental performance to environmental disclosure and no evidence of reverse causation.

Future research could examine whether these results hold for different measures of environmental performance, assuming that other general measures are available. Overall, we believe that both the association and causation results in this paper represent an advance in the empirical literature towards a firmer foundation capable of informing business strategy at corporate level and government policy at national and international levels. The over-arching policy conclusion from the analysis is that environmental performance, as measured by greenhouse gas emissions, is the corner stone in the CEP, CED and GHG troika. Thus, to improve economic performance and transparency at firm level, business strategy must pay very close attention to environmental performance. Environmental policy matters, not only for the environment but the economy as well.

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Table 1: Variable measurement summary

Variable	Measurement
CEP	Corporate economic performance measured by Tobin's Q ratio calculated as the sum of market capitalisation, total liabilities, preferred equity and minority interest, divided by total assets.
GHG	Corporate environmental performance measured by greenhouse gas emissions (millions of metric tonnes) or, if unavailable, by carbon dioxide (CO ₂) emissions.
CED	Corporate environmental disclosure score, which is a proprietary Bloomberg score based on the extent of a company's environmental disclosure.
SIZE	Firm size measured by turnover (US\$ millions) less an adjustment for items such as returns and discounts.
LEV	Financial leverage measured as net debt to equity as a proxy for financial risk.
CAP	Capital expenditure as a proxy for the efficiency of a firm in deployment of its assets.
BSZ	The number of full time directors on the company's board.
CEO	A dummy variable which equals one if the company's chief executive officer is also the chairman of the board and zero if the two roles are separate.
WOB	The proportion of women on the board of directors.
CHP	A dummy variable that equals one if the firm has a climate change policy describing its commitment to reduce greenhouse gas emissions through its ongoing operations and/or the use of its products and services and zero otherwise.
ENG	A dummy variable that equals one if the company has reported implementing initiatives to make its energy use more efficient and zero if the company has not explicitly disclosed any such efforts in its annual or company responsibility reports.
IND	A dummy variable that equals one if the firm is in the industrial, energy or utility sectors according to the Bloomberg Industry Classification System (BICS) and zero otherwise.
GDP	The gross domestic product per capita (US\$ current prices) in the firm's country of origin.
KYO	A dummy variable which equals one if the Kyoto Protocol is in force in the firm's country of origin and zero otherwise.
CCGP	The first principal component of corporate governance indicators at country level.

Table 2: Descriptive statistics and Spearman correlation matrix

	CEP	GHG	CED	SIZE	LEV	CAP	BSZ	CEO	WOB	ENG	CHP	IND	KYO	GDP	CCGP
Panel A: Spearman correlation matrix															
CEP	1														
GHG	-0.078 ^a	1													
CED	-0.089 ^a	0.251 ^a	1												
SIZE	-0.111 ^a	0.537 ^a	0.297 ^a	1											
LEV	-0.251 ^a	0.219 ^a	0.036 ^a	0.142 ^a	1										
CAP	-0.078 ^a	0.723 ^a	0.315 ^a	0.698 ^a	0.261 ^a	1									
BSZ	-0.090 ^a	0.283 ^a	0.216 ^a	0.449 ^a	0.122 ^a	0.398 ^a	1								
CEO	0.005	0.147 ^a	0.079 ^a	0.208 ^a	-0.029 ^a	0.165 ^a	0.130 ^a	1							
WOB	0.158 ^a	-0.012	-0.067 ^a	0.073 ^a	0.040 ^a	0.001	0.027 ^b	-0.051 ^a	1						
ENG	-0.060 ^a	0.121 ^a	0.366 ^a	0.139 ^a	0.043 ^a	0.152 ^a	0.079 ^a	0.020 ^c	-0.020 ^c	1					
CHP	-0.139 ^a	0.250 ^a	0.454 ^a	0.254 ^a	0.062 ^a	0.283 ^a	0.146 ^a	0.069 ^a	-0.080 ^a	0.309 ^a	1				
IND	-0.049 ^a	0.264 ^a	0.017 ^c	0.001	0.095 ^a	0.122 ^a	-0.019 ^c	0.055 ^a	-0.127 ^a	-0.021 ^b	0.059 ^a	1			
KYO	-0.208 ^a	-0.185 ^a	0.095 ^a	-0.174 ^a	0.000	-0.139 ^a	-0.090 ^a	-0.387 ^a	-0.241 ^a	0.122 ^a	0.147 ^a	0.009	1		
GDP	0.090 ^a	-0.008	-0.110 ^a	0.051 ^a	-0.001	0.014	-0.164 ^a	0.027 ^c	0.359 ^a	-0.070 ^a	-0.164 ^a	-0.026 ^b	-0.380 ^a	1	
CCGP	0.051 ^a	-0.123 ^a	-0.172 ^a	-0.111 ^a	-0.019 ^c	-0.113 ^a	-0.260 ^a	-0.292 ^a	0.253 ^a	-0.065 ^a	-0.148 ^a	-0.036 ^a	0.145 ^a	0.618 ^a	1
Panel B: Descriptive statistics															
Mean	1.57	4.82	35.55	15365	0.82	1066	11.21	0.27	13.27	0.89	0.63	0.32	0.80	43647	0.13
STD	1.28	15.92	14.08	21151	23.28	2139	3.44	0.45	11.36	0.31	0.48	0.47	0.40	16464	2.01

N= 9,120 firm-year observations. Superscripts a, b, c: correlations are significant at the 0.01, 0.05 and 0.10 levels (2-tailed) respectively.

Table 3: System estimation results

Dependent variable	Full Sample			Developed countries			Developing countries		
	CEP	GHG	CED	CEP	GHG	CED	CEP	GHG	CED
Intercept	0.981 ^a (0.000)	-8.013 ^a (0.003)	-0.262 (0.948)	1.705 ^a (0.000)	-12.136 ^a (0.000)	36.936 ^a (0.000)	2.055 ^a (0.000)	0.974 (0.878)	-11.543 (0.219)
CEP		-1.659 (0.234)	11.616 ^a (0.000)		-2.759 ^c (0.062)	-10.645 ^a (0.000)		-3.325 ^c (0.085)	14.716 ^a (0.000)
GHG	-0.037 ^a (0.000)		0.258 ^a (0.000)	-0.026 ^a (0.000)		-0.119 ^a (0.001)	-0.071 ^a (0.007)		1.380 ^a (0.000)
CED(-1)	0.014 ^a (0.000)	0.041 ^a (0.007)		-0.015 ^a (0.000)	0.078 ^a (0.000)		0.044 ^a (0.000)	0.301 ^a (0.000)	
SIZE	-3.3E-06 ^a (0.000)	1.4E-04 ^a (0.000)	7.4E-05 ^a (0.000)	-1.8E-06 ^a (0.000)	1.4E-04 ^a (0.000)	4.1E-05 ^a (0.000)	1.8E-05 ^a (0.000)	1.6E-04 ^a (0.000)	-8.1E-05 (0.123)
BSZ	-0.026 ^a (0.000)	0.264 ^a (0.002)	0.677 ^a (0.000)	0.004 (0.140)	0.113 (0.177)	0.527 ^a (0.000)	-0.074 ^a (0.001)	-0.114 (0.556)	0.739 ^a (0.006)
CEO	0.037 (0.115)	1.010 ^b (0.038)	1.584 ^a (0.000)	0.085 ^a (0.000)	1.752 ^a (0.003)	1.029 ^b (0.014)	0.334 (0.134)	1.448 (0.325)	-4.665 ^c (0.061)
WOB	0.010 ^a (0.000)	-0.002 (0.918)	-0.186 ^a (0.000)	0.015 ^a (0.000)	-0.044 ^b (0.011)	0.119 ^a (0.000)	0.005 (0.426)	0.083 ^b (0.040)	-0.201 ^a (0.005)
GDP	7.1E-06 ^a (0.000)	1.8E-04 ^a (0.000)	3.8E-05 ^c (0.062)	2.9E-06 ^b (0.017)	2.5E-04 ^a (0.000)	4.6E-05 ^b (0.026)	-6.0E-05 ^a (0.000)	-2.9E-04 ^b (0.014)	0.001 ^a (0.000)
CCGP	-0.091 ^a (0.003)	-0.823 ^a (0.000)	-0.003 (0.981)	-0.001 (0.924)	-0.387 ^a (0.005)	-0.574 ^a (0.000)	0.319 ^a (0.000)	1.837 ^a (0.003)	-5.021 ^a (0.000)
LEV	-0.001 ^a (0.000)			-2.9E-04 ^b (0.025)			-0.083 ^b (0.013)		
CAP	8.6E-05 ^a (0.000)			5.9E-05 ^a (0.000)			-1.1E-04 ^a (0.008)		
ENG		-1.377 ^b (0.014)			0.743 (0.186)			-0.123 (0.926)	
IND		4.429 ^a (0.000)			4.736 ^a (0.000)			3.889 ^a (0.005)	
CHP			10.196 ^a (0.000)			8.895 ^a (0.000)			5.930 ^a (0.000)
KYO			3.668 ^a (0.000)			-0.374 (0.727)			-4.244 (0.582)
S.E. of regression	1.16	15.34	17.14	1.05	15.87	16.07	1.56	11.55	24.03
N	7513	7513	7513	6729	6729	6729	784	784	784

P-values in parentheses. Superscripts a, b, c: correlations are significant at the 0.01, 0.05 and 0.10 levels (two-tailed) respectively. Full and developed country samples estimated by GMM, developing countries by 3SLS.

Table 4: Granger causality tests 2006–2014

Null hypothesis	Full sample		Developed countries		Developing countries	
	Wald-stat.	Decision	Wald-stat.	Decision	Wald-stat.	Decision
Dependent variable: CEP						
GHG does not Granger-cause CEP	11.648 ^a (0.003)	Reject	13.287 ^a (0.001)	Reject	0.317 (0.854)	Accept
CED does not Granger-cause CEP	9.271 ^a (0.010)	Reject	15.041 ^a (0.001)	Reject	2.592 (0.274)	Accept
GHG, CED do not Granger-cause CEP	22.467 ^a (0.000)	Reject	29.555 ^a (0.000)	Reject	3.045 (0.550)	Accept
Dependent variable: GHG						
CEP does not Granger-cause GHG	0.714 (0.700)	Accept	1.154 (0.562)	Accept	0.988 (0.610)	Accept
CED does not Granger-cause GHG	1.314 (0.518)	Accept	0.513 (0.774)	Accept	4.268 (0.118)	Accept
CEP, CED do not Granger-cause GHG	2.100 (0.717)	Accept	1.691 (0.792)	Accept	4.925 (0.295)	Accept
Dependent variable: CED						
CEP does not Granger-cause CED	1.586 (0.453)	Accept	3.838 (0.147)	Accept	2.962 (0.227)	Accept
GHG does not Granger-cause CED	10.065 ^a (0.007)	Reject	5.253 ^c (0.072)	Reject	21.929 ^c (0.000)	Reject
CEP, GHG do not Granger-cause CED	11.294 ^b (0.024)	Reject	8.952 ^c (0.062)	Reject	23.806 ^c (0.000)	Reject
N	6042		5452		590	

P-values in parentheses. Superscripts a, b, c: correlations are significant at the 0.01, 0.05 and 0.10 levels (two-tailed) respectively. Rejection of the null hypothesis implies that the explanatory variable Granger-causes the dependent variable. VAR lag length =2.