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Voluntary disclosure, greenhouse gas emissions and business performance: Assessing the first decade of reporting

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ABSTRACT

This study explores the empirical relationships between GHG emissions and an extensive range of business performance measures for UK FTSE-350 listed firms over the first decade or so of such reporting. Despite the popular and policy generated environmental imperatives over this period—along with growing evidence of the corporate added-value of having an 'environmental conscience', voluntary disclosure of emissions has been slow to adopt by firms. The leading contribution is to present clear evidence of a non-linear relationship, initially increasing with firm performance and then decreasing. An extensive pattern of non-reporting of emissions is also observed over time, and prior literature has introduced questions of endogeneity existing between firm performance and emissions. Steps are taken to ensure confidence/robustness of the results to these concerns. Accordingly, a two-stage (Heckman-type) selection model is used to analyse the emissions-performance nexus *conditional* upon the firm choosing to report (i.e. treating the choice to report as being endogenously determined with firm performance). From this—in addition to confirming the robustness of the non-linear relationship—it can be observed that the decision to report emissions is not directly influenced by wider social/governance disclosure attitudes of a firm, thus suggesting that firms disassociate environmental responsibility from social responsibility.
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1. Introduction

Since before climate change had become a recurring central policy issue there has been a long-standing research imperative to better understand the relationship between pollutant emissions and economic activities. Hitherto, empirical investigation into the relationship between activity and emissions has been conducted at the household-level (see, for example,Cox, Collins, Woods, & Ferguson, 2012; Kahn, 1998), but more extensively at the sectoral and economy-wide level (see, for example, the considerable range of such studies surveyed in Dinda, 2004; Nahman & Antrobus, 2005 and Stern,

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2004). With the exception of Konar and Cohen (2001) (who analyse the relationship between U.S. toxic chemical release data and stock market value), and Wen-Hsin Hsu and Wang (2013) (who analyse the impact of U.S. *mandatory* greenhouse gas reductions on stock market value), relatively little methodologically comparable research, nor similarly extensive and direct investigation of emissions exists at the firm-specific level. More indirectly, however, there are many studies framed in terms of analysing environmental management activities, environmental innovation, technology adoption and other environmental performance measures, alongside participation in particular environmental programmes requiring mandatory or voluntary compliance (see, for example, Brunnermeier and Cohen, 2003; Carrión-Flores & Innes, 2010; Cole, Elliott, & Shimamoto, 2006; Frondel, Horbach, & Rennings, 2008; Kassinis & Vafeas, 2006; Wagner, 2010; Wagner, Van Phu, Wehrmeyer, & Azomahou, 2002). Horváthová (2010) undertakes an extensive review of this work and reports on a meta-regression of 64 outcomes from 37 empirical studies in the “firm-environmental performance nexus” and finds,

> “ …. that the likelihood of finding a negative link between EP (*environmental performance*) and FP (*financial performance*) significantly increases when using the correlation coefficients and portfolio studies. On the other hand, the use of multiple regressions and panel data technique has no effect on the outcome. This suggests that it is important to account for omitted variable biases such as unobserved firm heterogeneity. The results also suggest that appropriate time coverage is important in order to establish a positive link between EP and FP. This suggests that it takes time for environmental regulation to materialise in financial performance.” p.56.

Horváthová's (2010) review also seems to point to a paucity of robust, extensive empirical GHG emissions-performance studies over a reasonable time frame at the firm-level. This is despite numerous lobby group, media and Government policy-led exhortations to, and initiatives for, firms to reduce their level of GHG emissions. These are generally framed as parts of various concerted actions to combat climate change and encourage permanent adoption of more environmentally sustainable modes of production.

Thus, this study explores the empirical relationship between a very extensive range of the most typically reported and deployed business performance measures and reported GHG emissions (all readily accessible via the Bloomberg (2016) database) for UK FTSE-350 listed firms over the period 2000 to the end of 2015.

The main contribution of this study lies in the clear evidence of a non-linear relationship between firm performance and emissions, with the effect initially increasing with firm performance and then decreasing after firm performance reaches a certain level. This conclusion is subjected to scrutiny, and after controlling for various factors that may be deemed to influence the result, is shown to be robust. Specifically, it is acknowledged that there is more than one way to measure performance, and after testing various alternatives, it is seen that this itself does not change the core conclusions. Further it is possible, as suggested in some prior research, that firm performance and emissions might be endogenously related. Data limitations do not make it easy to adopt traditional instrumental variable techniques; therefore, an endogenous selection model is used instead (treating the decision to report as the key endogenous step) that does not eliminate the non-linear effects. Additional explorations using the so-called ‘special regressor’ method due to Lewbel (2012), which adopts a non-standard IV approach using synthetic instruments, again fails to dismiss the existence of non-linear effects.

The remainder of this paper is organized as follows. The next section provides some background to the basis, advantages and limitations of the most common business performance indicators used. A brief retrospect on the guiding theoretical and empirical literature pertaining to emission-firm performance linkages is then presented which informs the choice of key hypotheses investigated. Then an attempt is made to distil these key concepts and direct them towards an underpinning theoretical framework to inform the subsequent empirical work. Data issues and the modelling strategy employed are considered in the following two sections. The results are then presented and discussed with a summary of findings and some concluding remarks proffered in the final section.

2. Measuring performance

It is important to consider a comprehensive range of different accepted measures of performance, as businesses have many stakeholders (such as shareholders, bankers, employees, and tax authorities) whose interests in the firm differ (Johnston & Pongatichat, 2008). Shareholders, for instance, may focus more on profits, whilst bankers focus on both cash-flow-related performance metrics, such as operating cash flows and capital structure. On the contrary, tax authorities may focus on profit before tax and employees on sales. Besides, accounting policies (e.g. depreciation method) or differences on capital structure or financing decisions (e.g. leasing) induce performance asymmetries in the short run that necessitate the need to account for alternative performance measures. The broad range of business performance measures used in this study are *Sales*, *Net Income, Operating Profits, Market Capitalisation, Stock price*, *Asset, ROE (Return on Equity)*, *Tobin's Q* and *EBITDA (Earnings Before Interest, Tax, Depreciation and Amortization*). Definitions and a brief explanation of the examined measures are set out in Table 1.

2.1. Firm performance and polluting emissions: A brief theoretical retrospect

The analysis of pollution by firms has a long and distinguished history and its chronological context is set out in Kula (1998) and Pearce (2002). Early contributions set out what has emerged to serve as a very durable stylized picture of a profit-maximizing firm treating the atmosphere and other environmental media, such as seas and river basins, as essentially free goods in which to emit or dispose waste. Economic theory therefore suggests that these free goods would be over-consumed by such firms to the material detriment of other firms and households, which would be expected to become manifest in terms of the external costs (negative externality) of pollution being imposed on others through clean-up costs, deleterious health effects etc. Such simple stylized thinking, supplemented by analyses of property rights (see, for example, Coase, 1960; Dales, 1968) has informed the structuring and application by environmental regulators of a range of command and control instruments (total bans, emission standards, fines) as well as of economic incentive instruments (taxes, subsidies, tradable permits); for an overview see Baumol and Oates (1988). These were intended to reduce or optimize the level of polluting emissions and were justified with reference to various measures or indicators of societal preferences. In principle, however, such regulatory interventions would still need to be mindful of the neoclassical economic implication of profit maximization that firms would only expend the minimum cost necessary to comply with any given regulatory intervention and even weigh up the net cost implications of bypassing such interventions if monitoring, enforcement and punishment were weak.

Another theoretical strand, however, drawing initially and principally on case study evidence, recasts this body of theory premised on the assertion that increasing regulatory stringency may actually be profitable rather than costly (Porter, 1991; Porter & van der Linde, 1995). This argument, generally labelled 'the Porter hypothesis' is explained in terms of the stimulus to innovation afforded by tighter mandatory environmental regulations prompting cost-saving productive efficiencies. The conceptual and empirical basis for the hypothesis has been contested and augmented for testing in 'weak', 'narrow' and 'strong' forms (see, for example, Ambec, Cohen, Elgie, & Lanoie, 2013; Jaffe & Palmer, 1997; Lanoie, Laurent-Lucchetti, Johnstone, & Ambec, 2011; Palmer *et al.,* 1995). In weak form it is simply asserted that environmental regulations can stimulate innovation. The narrow form suggests that flexible environmental policy regimes can better incentivise innovation than less flexible environmental policy regimes and the strong form suggests that well designed regulation can induce cost-saving innovations outweighing the costs of compliance with such regulations.

In a related vein, further theoretical strands of the firm-pollution emission discourse have also explored the motivations and scope for actually fostering voluntary over-compliance – i.e. abating emissions some way above the minimum (statutory) requirement (Anton, Deltas, & Khanna, 2004; Arora & Gangopadhyay, 1995). The very existence of this practice might appear to pose a serious challenge to neoclassical economic conceptions of firm practice. This arises since the required information to voluntarily indicate or demonstrate over-compliance entails (i) disclosure of potentially strategically valuable information to competitors and regulators and (ii) voluntarily incurring the costs of collecting the emissions information. At the very least, such economic theory might be recalled to support the view that the practice would not be widespread and perhaps related to distinct competitive environmental strategies where signalling 'green' or climate change combative credentials offer 'legitimacy' (see, for example, Cho & Patten, 2007) or has market value. Indeed in some other theoretical studies voluntary over-compliance has simply been conceptualized as exercises in 'greenwash' i.e. simply augmenting marketing spend (see, for example, Kim & Lyon, 2011; Mahoney, Thorne, Cecil, & LaGore, 2013).

In other cases the undertaking of voluntary over-compliance has simply been related to differences in regulatory stringency across countries and thereby offering, for example, some foreign direct investing firms competitive advantages by default, simply through their experience in their host country. Essentially, if regulatory stringency is expected to be on an upward trajectory in the country being invested in, then this intrinsic competitive advantage could be reinforced via green branding and marketing tactics and also accentuated as domestic firms struggle (in cost terms) to comply with tougher regulations. However, over-compliance may also arise for both foreign direct investing and domestic firms due to a desire to exploit cost-saving efficiency improvements that raise resource productivity by the firm, i.e. leading to the generation of less waste or emissions per unit of natural resource inputs used in production. This may emerge from resource productivity improvements in the mainstream production process of the firm or the greater use of the waste by-products in new or other production lines. Nevertheless, it remains an open empirical question in different market contexts, whether or not more efficient firms spend more or less on pollution abatement than less efficient firms. For instance, there are conspicuous contrasts in the efficiency-pollution abatement spending relationship for the UK metal manufacturing and chemical industries presented in Collins and Harris (2002 and 2005).

At the heart of this question lies an extensive related thread of literature concerned with establishing the veracity or otherwise of the 'Jevons Paradox' and its more contemporary evocation as 'the rebound effect' (see, for example, Saunders, 1992; Turner & Hanley, 2011). Jevons conjectured that technological progress leading to greater resource productivity (in his context, more efficient use of coal) actually provided the scope and means for increasing coal demand. Saunders (1992) assessed the gains specifically from energy resource efficiency within the context of various economic growth assumptions and found that some level of rebound effect was present. The idea that energy resource efficiency may actually be a less environmentally successful strategy than commonly thought has provided a source of fierce academic contention centring on the extent to which energy efficiency improvements in some individual firms and markets are technically connected to sectoral and economy-wide energy resource consumption.

Among the extant literature there also features a voluminous number of studies focusing on a conjecture termed the environmental Kuznets curve (EKC). This literature postulates with various implicit and/or explicit assumptions and conditions that the rate of emissions reduces with the scale of activity, but, moreover, after a certain level of activity, that the level of emissions may also reduce in absolute terms (Dasgupta, Laplante, Wang, & Wheeler, 2002; Dinda, 2005; Kijima, Nishide, & Ohyama, 2010).

Table 1
Measures of business performance and capital structure.

Measure	Variable name	Definition and Explanation
Money metric based performance measures		
Sales (also called *Turnover*)	SALES	Direct measure of business performance, because indicates business generating activity, and emission generating activity
EBITDA 'Earnings Before Interest Tax Depreciation and Amortization	EBITDA	Operating Profits before the deduction of non-cash items Depreciation and Amortization. Company performance measure. EBITDA margin is a measure of the profitability and short-term company performance.
Net Income, also known as After tax Profits	PROFITS	Profit of the firm, after Tax deductions. Important for shareholders because a proportion of Net Income is given to shareholders as dividends.
Operating Profits, is also known as Earnings Before Interest and Tax.	OPROF	Profits before interest and taxation. Proxy of company performance, and proxy of company's operating cash flows.
Market Capitalisation is the value of the firm in capital markets.	MCAP	Market Capitalisation is the number of shares outstanding times the share price. Measure of value and hence performance independent of the firms' accounting policy. Measure of the company size, as well.
Asset, denotes the Total Assets at the end of the period.	ASSETS	Measure of the size of the firm.
Ratio based performance measures/measures that cannot be scaled by number of staff		
Stock price	PRICE	Reflects company performance as evaluated by the shareholders, scaled by the number of shares.
ROE - Return on Equity	ROE	Net Income over Average Equity. Average Equity denotes the average Equity during a Fiscal Year. It is a measure of profitability from the perspective of the Shareholders.
Tobin's Q	TOBQ	Market Value of the company over the Replacement Value of its assets. Tobin Q over Total Assets is indication of long-term performance

Contradictory evidence has been found affirming and disputing the presence of environmental Kuznets curves at different levels of aggregation (see, for example, Bertinelli & Strobl, 2005; Chimeli & Braden, 2005; Dinda, 2004; Fernández, Peréz, & Ruiz, 2012; Millimet, List, & Stengos, 2003; Perman & Stern, 2003). Nevertheless, some extension of this thinking into the corporate sector might have been expected to systematically investigate the potential widespread (cross-sectoral) existence of such curves with respect to GHGs at the firm-level, even though more difficult questions do arise as to the appropriate choice of a particular activity measure. In the related literature at the macro, sectoral and household level, income is generally used as the measure of activity. However, it would be reasonable to assert that business performance metrics are the more appropriate activity indicator at the firm level. Firms who perform better have arguably greater flexibility to invest in emissions-reducing activities, noting that these are sometimes both high upfront cost investments as well as low direct return investments.

Firms that are not performing so well will have less financial scope to take such emission abating actions. However, measuring performance is itself a difficult task, and arguably there is no clear single specific measure of performance for a firm. The main reason for this is that firms have different stakeholders who are interested in different objectives, and also that multinational firms may well have similar stakeholders from different geographic regions that may well place more or less importance on the same objectives.

2.2. Towards an underpinning theory of corporate environmental Kuznets curves

In light of the theoretical and empirical discourse outlined and discussed in the previous section, we distil some key concepts that may maybe be harnessed to support the beginnings of an underpinning theory to help explain corporate environmental Kuznets curves. This theory is situated in the business performance-emissions nexus and used to advance three simple but key hypotheses warranting empirical investigation.

The most fundamental key concept (based on the first and second laws of thermodynamics) is that there is always a clear positive relationship in industrial production between the generation of outputs (goods) and the generation of emissions/waste (bads). For a given firm's plants, the exact proportion of 'goods' and 'bads' is an open empirical question premised on (i) the technical efficiency of production and (ii) the degree to which emission and waste costs are effectively internalised to the firm. A lower proportion of 'bads' implies higher resource productivity (output/resource inputs [Y/R]) contributing to cost reduction in the firm. For 'reasonable' values of (i) and (ii), resource productivity should be positively related to business performance (π) over some range of output but with diminishing returns setting in thereafter. As such the relationship between Y/R and π might be theoretically posited to follow an inverted 'U' shaped pattern and thus underpin a similar pattern in an emission − business performance metric relationship.

To begin to empirically explore the logic and bounds of this simple theoretical framework in the light of voluntary disclosure of GHG emissions by firms, we posit the following hypotheses:

Hypothesis 1. *Firms' Greenhouse gas emissions are dependent on firm performance and more specifically are subject to an environmental Kuznets-type curve.*

Hypothesis 2. *Business performance measures are not related to emissions identically.*

Hypothesis 3. *Voluntary disclosure of greenhouse gas emissions affects the nature of the emissions-business performance relationship.*

3. Data

The data are taken from the Bloomberg (2016) database and include all firms listed in the FTSE 350 index since 2000, and includes all available data up to the end of 2015. In principle, this data allows for several thousand firm-year observations, however, a significant amount of non-reporting of emissions among firms substantially reduces the sample sizes available for econometric work. Table 2 presents descriptive statistics for the FTSE 350 data, including measures for the firms that report emissions, selected statistics for those that do not report and also for the full sample. These are generally firms whose primary business activity is in the UK, though most of the firms on the list are multinational firms, hence, the data encapsulates exposure to international business practices and standards/regulations.

The main variable of interest is the self-reported level of emissions, which include all greenhouse gas emissions reported by the business that were created by the activity of the business.[1] This includes a basket of gases that includes, but is not restricted to carbon dioxide emissions. The definition of business activity is quite general and does potentially incorporate both direct and indirect emissions, whereby the direct emissions are those which the reporting firm has direct control over, and the indirect emissions are those in which the firm has little or no direct control over, for instance elements of the wider supply chain.[2]

4. Modelling strategy

The empirical approach connecting firm level emissions and the various performance indicators is based upon the type of models observed in the EKC literature, in which the model allows for a non-linear relationship in the form of a quadratic curve (see, for example, Kijima et al. (2010). Equation (1) depicts the equation to be estimated:

$$e_{it} = \alpha + \beta_1 p_{it} + \beta_2 {p_{it}}^2 + \sum_{i=2}^{I} \delta_i D_i + \sum_{t=2}^{T} \delta_t D_t \tag{1}$$

Where e is the greenhouse gas emissions divided by the number of staff, and p is the performance indicator. The performance indicators are of two types, some are money metrics, and others are ratios: the money metric performance measures (SALES, EBITDA, PROFITS, OPROF, MCAP and ASSETS) are divided by the number of staff, while the remaining measures (PRICE, ROE and TOBQ) are not. D_i and D_t are dummy variables to control for industry specific and time specific effects, where the model intercept α represents the base industry and base time period. Firm specific fixed effects were considered, but limitations in data reporting preclude this as being viable. β_1 and β_2, which are the coefficients describing the existence and nature of relationship between firm performance and emissions, are the main parameters of interest.

To provide the most robust estimates possible, and ensure that parameter inference is robust to any heteroskedasticity the linear equations in (1) are estimated using a non-parametric bootstrap regression. The (residual based) bootstrap procedure provides inference upon a statistical model by using the ordinary least squares (OLS) residuals to represent the empirical distribution of shocks. These residuals are recorded, and re-ordered across the observations to allow any given observation to be subject to a different error, subsequently the model is re-estimated by OLS and the coefficients are recorded as individual runs of a bootstrap. Thus, the bootstrap process evaluates how stable the estimated coefficients are to different data, where the differences in data are based on observed (unexplainable) variability. This is in effect the purpose of conventional (asymptotic) inference, but no longer depends on either normality of the residuals nor large sample sizes. See Davison and Hinkley (1997); Efron and Tibshirani (1993) and for further detailed discussion of non-parametric regression by least squares. The results reported in the following section concentrate on the mean coefficient value and the 95% confidence interval from 1000 bootstrap replications.

4.1. Correcting for self-reporting bias/endogeneity

It is possible that firm performance and the decision to report emissions are jointly determined, a concern that has been presented in a number of prior research studies. In such a case, there is a risk that the endogenously determined behaviours may lead to statistical bias in the estimated parameters, thereby rendering invalid any conclusions drawn from simple OLS

[1] We appreciate and would like to recognize the valuable suggestion by an anonymous reviewer to explore the European Pollutant Release and Transfer Register as a potential source of additional data. This very interesting data captures site-level pollutant emissions from around 30,000 plants across Europe, but unfortunately contains data only from industrial sites, and therefore does not provide sufficient coverage to match many of the firms included in our data sample that are drawn from other sectors, and so was not considered further here.

[2] There is a possible concern that since firms have proxy over their reporting standards, they may not report perfectly comparable pollutant levels. There is no way for this to be confirmed with the available data, though it is assumed that the reporting practices will be, by and large, consistent and hence comparable across firms.

based approaches. To account for possible selection bias, the emissions function is re-estimated as a Heckman-type selection problem. The latent system equations can be written as:

$$e_{it}^{S*} = \alpha^S + \beta_1^S Disclosure_{it}$$

$$e_{it}^{O*} = \alpha^O + \beta_1^O p_{it}^O + \beta_2^O p_{it}^{O^2} + \sum_{i=2}^{I} \delta_i^O D_i^O + \sum_{t=2}^{T} \delta_t^O D_t^O \quad (2)$$

Where:

$$e_{it}^{O} = \begin{cases} 0 & \text{if } e^{S*} = 0 \\ e_{it}^{O*} & \text{Otherwise} \end{cases}$$

That is to say that the emissions for any given firm are only observed when the selection variable eS*is positive. The Bloomberg database includes proprietary measures of environmental disclosure (ED), social disclosure (SD) and governance disclosure (GD), which are a natural choice of instruments for the selection equation:

$$e_{it}^{S*} = \alpha^S + \beta_1^S ED_{it} + \beta_2^S SD_{it} + \beta_3^S GD_{it}$$

4.2. A note on additional alternative estimation procedures

It is common practice in situations where endogeneity is expected to exist, to adopt an instrumental variable (IV) approach. In IV regressions, the variable expected to be endogenously connected with the outcome of interest, in our case the measure of firm-performance, needs to be instrumented using a proxy-variable that exhibits a high correlation with firm performance, but a low correlation with the residuals from a standard OLS regression of the emissions model in equation (1). Finding statistically valid instruments can be a challenging task in many applications, and in the present study it was not possible to conceive or easily identify valid instruments that would permit traditional IV regressions to be adopted.

Failing to identify a valid instrument does not however mean that endogeneity bias is not a concern. Recognising that there are many cases in which valid instruments are difficult to identify, Lewbel (2012) has suggested an innovative new approach for IV analysis known as known as ‘special regressor’, whereby valid instruments are synthetically generated using the available and expected endogenous variables. Therefore, **no** exogenous instruments need to be identified (although they can still be included if available). One might extend a degree of scepticism at first, since this sounds, in many ways, too good to be true. However, Lewbel (2012) is well sighted and the approach appears to be gaining traction in econometric research; furthermore, the work fully develops the relevant asymptotic theories and offers Monte-Carlo evidence to highlight its accuracy/power. The full details of this ‘special regressor’ procedure are not presented here; however, can be found in Lewbel (2012) and related references.

The ‘special regressor’ model is therefore applied here as another way to handle potential endogeneity effects. This allows the level of firm performance (and its square) to be treated as endogenous terms. This approach differs from the Heckman selection model which instead of modelling the levels of firm performance, treats the decision to report as endogenous. Thus results from these two approaches are complementary to each other, exploring different sources/stages of endogenous relationship.

5. Results and discussion

This section presents and discusses the main results, taking each of the aforementioned hypotheses in turn.

Hypothesis 1. *Firms' Greenhouse gas emissions are dependent on firm performance and more specifically are subject to an environmental Kuznets-type curve. If either of the linear or squared emissions terms is insignificant, then the Kuznets relationship can be rejected. This implies the following null hypothesis*:

$$H1^{(1)}: \text{ Both } \beta_1 \text{ and } \beta_2 \neq 0$$

Tested against the null hypothesis that either one of these are equal to zero. This can be evaluated using individual coefficient significance testing procedures.

Tables 3 and 4 report the estimation results for CO2 and GHG emissions respectively based on Equation (1). Across the columns of these tables it is evident that there is a broad dichotomy between the two types of performance measures. For each of the alternative money metric based performance measures, with the exception of SALES, give strong evidence of a non-linear inverted U-shape relationship between performance and emissions. For SALES the coefficient values broadly

Table 2
Descriptive statistics.

Performance measure:	Estimation data (reporting firm-years)								All firm-years				Non-reporting firm-years			
	means	max	min	sd	skew	kurtosis	observed	missing	means	sd	observed	missing	means	sd	observed	missing
CO2	5179.828	86980	0.323	13586.01	3.477	12.735	688	1775	5179.828	13586.010	688	6257				
GHG	2637.018	95119	0.079	9814.267	5.634	36.412	2147	316	2637.018	9814.267	2147	4798				
SALES	9523.652	470171	−31076	35188.39	8.955	91.977	2444	19	5747.443	25543.222	5667	1278	4682.451	22107.901	669.000	1259.000
EBITDA	1302.949	57301	−4240	4516.543	7.51	68.271	2217	246	789.400	3370.052	5176	1769	622.312	2833.134	4565.000	1692.000
PROFITS	776.714	18938.23	0.17	1066.105	6.572	82.063	2438	25	668.413	1584.338	6213	732	661.263	1651.262	5537.000	720.000
OPROF	856.736	43645	−10340	3246.32	7.569	72.43	2225	238	513.439	2403.501	5213	1732	408.947	1980.952	4603.000	1654.000
PRICE	776.714	18938.23	0.17	1066.105	6.572	82.063	2438	25	668.413	1584.338	6213	732	661.263	1651.262	5537.000	720.000
MCAP	8110.376	155859.2	0.713	18349.85	4.191	20.136	2438	25	5058.658	14020.305	5520	1425	4066.975	11164.577	4844.000	1413.000
ASSETS	44849	2692538	38.544	214529.6	8.547	83.794	2444	19	25334.536	152070.827	5664	1281	15976.769	86741.402	4995.000	1262.000
ROE	23.268	2409.862	−208.894	83.691	15.262	355.123	2423	40	20.363	67.899	5435	1510	18.710	66.192	4776.000	1481.000
TOBQ	1.789	80.938	0.323	2.618	23.32	641.372	2426	37	1.862	2.537	5352	1593	1.884	2.687	4685.000	1572.000
ind_1	0.076	1	0	0.264	3.211	8.314	2463	0	0.056	0.230	6945	0	0.058	0.233	6257.000	0.000
ind_2	0.181	1	0	0.385	1.655	0.741	2463	0	0.173	0.378	6945	0	0.167	0.373	6257.000	0.000
ind_3	0.19	1	0	0.393	1.576	0.484	2463	0	0.153	0.360	6945	0	0.156	0.363	6257.000	0.000
ind_4	0.004	1	0	0.064	15.589	241.106	2463	0	0.002	0.046	6945	0	0.002	0.042	6257.000	0.000
ind_5	0.054	1	0	0.226	3.944	13.562	2463	0	0.060	0.238	6945	0	0.059	0.236	6257.000	0.000
ind_6	0.192	1	0	0.394	1.559	0.432	2463	0	0.305	0.460	6945	0	0.321	0.467	6257.000	0.000
ind_7	0	0	0	0	NA	NA	2463	0	0.002	0.046	6945	0	0.002	0.049	6257.000	0.000
ind_8	0.143	1	0	0.35	2.039	2.16	2463	0	0.110	0.313	6945	0	0.103	0.304	6257.000	0.000
ind_9	0.028	1	0	0.165	5.717	30.697	2463	0	0.041	0.198	6945	0	0.043	0.202	6257.000	0.000

Note: SALES, EBITDA, PROFITS, OPROF, MCAP, ASSETS are in million British pounds. ROE in percentage terms, PRICE in British Pounds. CO2 refers to carbon dioxide emissions, and GHG refers to the wider set of greenhouse gas emissions.

support the idea of an inverted U-shape, however the 95% confidence interval for the quadratic term passes through zero i.e. the confidence interval includes both positive and negative values, but whose range is predominantly negative. The absolute values of the coefficients in each of the columns vary, but this is to be expected given the different definitions of performance.

For the performance measures that are based on ratios, a slightly different picture emerges. The patterns are much less consistent, with less significance visible on the parameter estimates. Nonetheless the U-shape finding for PRICE stands out clearly among the various performance measures. Compared with the other performance measures PRICE might be considered relatively more exogenous to the firm,[3] since stock prices respond to the actions and choices of financial analysts and investors who themselves may factor in information beyond the firm-specific fundamentals, such as the wider stability of the financial market and broader economic conditions that will also in part determine the demand for speculative investment behaviours and in turn a part of PRICE. An interesting implication of this finding is that environmentally conscious investors might have a preference towards mid-priced stocks, where 'mid' is loosely used here to refer to the region of the optimum on the U-shaped curve. Taking the results together, the evidence strongly supports the first hypothesis stating that emissions are functionally dependent on firm performance. Further evidence of a U-shaped relationship can be seen for some of the other ratio-based performance metrics also, suggesting this is not an incidental finding.

As discussed, Tables 3 and 4 strongly favour the existence a relationship between emissions and firm performance does exist and moreover is broadly in terms of a non-linear Kuznets-type relationship, albeit one that is slightly sensitive to the definition of performance. The performance measures considered here have been grouped into two types, based on their ability to be scaled by the number of firm employees. The difference between these two groups therefore can be attributed in part to the scale effect embedded in the per-employee transformation. In light of this the findings have one rationale being that when the physical scale of a firm is taken into account, it is much more likely that a relationship with emissions will be revealed. A complementary interpretation to this is that the ratio-based performance measures do not take sufficient account of the physical operations of the firm and their associated emission rates. Since these latter performance measures are arguably framed more towards illuminating financial performance/stability than the other measures, then this might indicate that financial stability or instability need not be a justification for sustaining yet higher levels of emissions.

Hypothesis 2. *Business performance measures are not related to emissions identically.*

Each of the performance measures are defined in different metrics, which is a direct result of their unique purposes. For example, TOBQ is a ratio intended to reflect an eclectic snapshot of overall firm performance and has a fundamentally different metric to SALES, with the latter being expressed in an easy to understand money metric. It stands to reason that their relationships with emissions should differ. To evaluate this hypothesis requires comparing in some way the same coefficients from the same model structures, but with different performance measures included on the right hand side. There are a number of ways that such hypotheses could be formulated, but a pragmatic approach is taken here.

As discussed with regard to the previous hypothesis, there are some substantial differences in how performance measures of different types are related to emissions. The fact that some illustrates significant Kuznet's-type curves, and others do not, is sufficient evidence so as to be unable to reject Hypothesis 2. No attempt is made here to reconcile such differences; rather the purpose here is to highlight their existence. These differences pose interesting concerns for environmental impact management, inasmuch as firms pursuing different performance objectives may be reasonably able to justify several alternative emissions levels as being admissible. Although not a focus of the present paper, it is abundantly clear that to reconcile their differences is a pressing priority for future study.

Hypothesis 3. *Voluntary disclosure of greenhouse gas emissions affects the nature of the emissions-business performance relationship.*

This hypothesis is evaluated using the coefficient values from a Heckman-type selection type model which makes corrections for self-selection into emissions reporting.

The results to this point provide compelling evidence that a firm-level environmental Kuznet-curve does exist, but that it can be sensitive to the choice of performance measure used. The aim here is to consider the possibility that the conclusions so far might be sensitive to possible bases that can arise when modelling data involving self-selection (or pre-determined choices). Table 2 highlights the level of attrition in the dataset regarding the reporting of emissions, with only 688 observations being available from an initial sample of almost 7000 observations in principle. For the performance measures used, there is virtually full and complete data either from the stock market or from the mandatory company accounts. Hence, the level of attrition in reported emissions is due to self-selected non-reporting. In general over the sample period there has been no specific requirement on firms to report their emissions; however, some firms have chosen to adopt transparency principles as part of their corporate social responsibility activities. Giving a transparent view of emissions levels potentially serves as a signal to stakeholders of the integrity of a given firm, which could in turn generate some intangible added-value for the firm in terms of environmental warm-glow and/or customer and investor loyalty. An alternative view is that it simply provides

[3] We would like to acknowledge here some useful points raised by an anonymous referee. The variable PRICE is among the most encompassing measures of performance considered in this study, since it reflects all dimensions of firm behavior, from investment and financing decisions through to the activities connected to emissions. However, while it is encompassing as a measure of performance, this alone does not eliminate the influence of exogenous investor behavior upon the corporate stock price. A type of exogenous influence that will be less apparent in many of the other performance measures. Hence *relatively more* exogenous.

Table 3
CO_2—*95% bootstrap confidence interval in brackets.*

Performance measure:	Money metric performance measures (per employee)						Ratio based performance measures		
	SALES	EBITDA	PROFITS	OPROF	MCAP	ASSETS	PRICE	ROE	TOBQ
Level term	**3.0609**	**6.7997**	**6.5639**	2.7389	**1.5475**	**0.1842**	**−0.0005**	**0.0052**	**0.7492**
	(2.2626, 3.9508)	(3.8319, 9.8654)	(5.0951, 7.9808)	(-0.4214, 5.7047)	(1.0452, 2.0498)	(0.0511, 0.3104)	(-0.0010, −0.0001)	(0.0001, 0.0113)	(0.1444, 1.3844)
Squared term	**−0.4189**	−2.4412	**−2.7026**	2.8278	**−0.1352**	**−0.0063**	**0.0000**	**0.0000**	**−0.1026**
	(-0.6325, −0.2013)	(-4.8815, 0.3686)	(-3.5366, −1.8115)	(-0.4163, −6.7422)	(-0.2140, −0.0485)	(-0.0116, −0.0022)	(0.0000, 0.0000)	(0.0000, 0.0000)	(-0.1899, −0.0095)
Observations	669	611	667	610	667	669	667	659	667

Note: SALES, EBITDA, PROFITS, OPROF, MCAP, ASSETS are in million British pounds. ROE in percentage terms, PRICE in British Pounds.
Bold is used to indicate when the highlighted coefficient is constant i.e. when the upper and lower bounds of the confidence interval take the same sign.

Table 4
Greenhouse gases—*95% bootstrap confidence interval in brackets.*

Performance measure:	Money metric performance measures (per employee)						Ratio based performance measures		
	SALES	EBITDA	PROFITS	OPROF	MCAP	ASSETS	PRICE	ROE	TOBQ
Level term	**0.4111**	**0.4720**	**0.1307**	**0.3882**	**0.0580**	**0.0483**	−0.0001	−0.0007	−0.0287
	(0.3629, 0.4787)	(0.4156, 0.5555)	(0.1005, 0.1726)	(0.3201, 0.4724)	(0.0481, 0.0751)	(0.0408, 0.0595)	(-0.0001, −0.0000)	(-0.0014, 0.0003)	(-0.0679, 0.0169)
Squared term	**−0.0064**	**−0.0190**	**−0.0034**	**−0.0163**	**−0.0005**	**−0.0004**	**0.0000**	**0.0000**	0.0004
	(-0.0085, −0.0050)	(-0.0232, −0.0163)	(-0.0046, −0.0026)	(-0.0201, −0.0132)	(-0.0006, −0.0004)	(-0.0005, −0.0003)	(0.0000, 0.0000)	(0.0000, 0.0000)	(-0.0002, 0.0009)
Observations	2132	1931	2122	1940	2122	2132	2122	2122	2119

Note: SALES, EBITDA, PROFITS, OPROF, MCAP, ASSETS are in million British pounds. ROE in percentage terms, PRICE in British Pounds.
Bold is used to indicate when the highlighted coefficient is constant i.e. when the upper and lower bounds of the confidence interval take the same sign.

Table 5
CO_2 with control for sample selection—*asymptotic p-value in brackets.*

Performance measure:	Money metric performance measures (per employee)						Ratio based performance measures		
	SALES	EBITDA	PROFITS	OPROF	MCAP	ASSETS	PRICE	ROE	TOBQ
Selection equation									
Environmental disclosure	**0.023**	**0.020**	**0.023**	**0.020**	**0.023**	**0.023**	**0.023**	**0.023**	**0.023**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Social disclosure	−0.000	0.002	−0.000	0.001	−0.000	−0.000	0.000	0.000	0.000
	(0.93)	(0.63)	(0.92)	(0.62)	(0.92)	(0.93)	(0.92)	(0.92)	(0.92)
Governance disclosure	**−0.007**	−0.002	**−0.008**	−0.002	**−0.008**	**−0.008**	**−0.008**	**−0.007**	**−0.008**
	(0.04)	(0.57)	(0.04)	(0.65)	(0.04)	(0.04)	(0.04)	(0.06)	(0.04)
Stage 1 observations	3225	3167	3223	3166	3223	3225	3223	3216	3223
Emissions equation									
Level term	**3.044**	**6.913**	**6.715**	2.873	**1.553**	**0.167**	**−0.005**	0.005	**0.761**
	(0.00)	(0.00)	(0.00)	(0.12)	(0.00)	(0.05)	(0.07)	(0.19)	(0.05)
Squared term	**−0.404**	**−2.476**	**−2.720**	2.709	**−0.138**	−0.006	0.000	−0.000	**−0.103**
	(0.00)	(0.10)	(0.00)	(0.19)	(0.01)	(0.12)	(0.24)	(0.26)	(0.09)
Stage 2 observations	666	608	664	607	664	666	664	657	664

Note: SALES, EBITDA, PROFITS, OPROF, MCAP, ASSETS are in million British pounds. ROE in percentage terms, PRICE in British Pounds.
Bold is used to indicate when the highlighted coefficient is constant i.e. when the upper and lower bounds of the confidence interval take the same sign.

another basis to question management performance in a difficult to control area such that widespread withholding of GHG data or deliberate neglect to measure GHG emissions may be implicitly deemed preferable.

The results of the selection models are reported in Tables 5 and 6 respectively. The results in Tables 5 and 6 compare fairly closely with Tables 3 and 4, suggesting that the possible concerns that self-selection in to reporting may not be a source of major bias. Two notable differences come from the lack of significance for the PRICE performance measure under the selection model for CO_2, although if a 20% significance level is seen as acceptable, then the non-linear effect hypothesis still finds some support. For the ratio or money-metric based performance measures do continue to present some mild evidence of an inverted 'U' shape relationship. Controlling for the selection bias therefore has some impact on the observed relationship. For the ratio based performance measures the results are quite similar whether the selection model is used or not. The results for GHG are qualitatively very similar to those for CO_2, with the notable exception that the effects seen for PRICE become strongly significant.

Overall, mitigating against the possible bias incurred from self-selection into emissions reporting, the confidence in the results is greatly increased, and hence is the confidence in the existence of a firm-level Kuznets-type curve. Regarding

Table 6
Greenhouse gasses with control for sample selection—*asymptotic p-value in brackets.*

Performance measure:	Money metric performance measures (per employee)						Ratio based performance measures		
	SALES	EBITDA	PROFITS	OPROF	MCAP	ASSETS	PRICE	ROE	TOBQ
Selection equation									
Environmental disclosure	**0.047**	**0.047**	**0.047**	**0.047**	**0.047**	**0.047**	**0.047**	**0.047**	**0.047**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Social disclosure	**0.016**	**0.017**	**0.016**	**0.017**	**0.016**	**0.016**	**0.016**	**0.016**	**0.016**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Governance disclosure	−0.005	−0.004	−0.004	−0.004	−0.004	−0.005	−0.004	−0.005	−0.004
	(0.19)	(0.39)	(0.27)	(0.39)	(0.27)	(0.19)	(0.27)	(0.18)	(0.27)
Stage 1 observations	3225	3024	3217	3033	3217	3225	3217	3221	3216
Emissions equation									
Level term	**0.415**	**0.478**	**0.013**	**0.394**	**0.059**	**0.049**	−0.000	−0.009	−0.027
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.42)	(0.13)	(0.34)
Squared term	**−0.006**	**−0.019**	**−0.004**	**−0.017**	**−0.000**	**−0.003**	**0.000**	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.75)	(0.27)	(0.44)
Stage 2 observations	2118	1917	2110	1926	2110	2118	2110	2114	2109

Note: SALES, EBITDA, PROFITS, OPROF, MCAP, ASSETS are in million British pounds. ROE in percentage terms, PRICE in British Pounds.
Bold is used to indicate when the highlighted coefficient is constant i.e. when the upper and lower bounds of the confidence interval take the same sign.

Table 7
'Special regressor' estimation results for CO2 (*p-value in brackets).*

Performance measure:	Money metric performance measures (per employee)						Ratio based performance measures		
	SALES	EBITDA	PROFITS	OPROF	MCAP	ASSETS	PRICE	ROE	TOBQ
Level term	**0.5965**	**13.7969**	−1.5646	0.0528	−0.0249	−0.0726	N/A	**−2.4935**	−50.3360
	(0.00)	(0.08)	(0.22)	(0.98)	(0.95)	(0.37)		(0.05)	(0.85)
Squared term	**−0.0756**	**−8.7969**	0.5671	0.8195	0.0065	0.0011	**N/A**	0.0026	−40.7240
	(0.00)	(0.09)	(0.21)	(0.64)	(0.91)	(0.59)		(0.14)	(0.38)
Observations	669	611	667	610	667	669	667	659	667

Note: SALES, EBITDA, PROFITS, OPROF, MCAP, ASSETS are in million British pounds. ROE in percentage terms, PRICE in British Pounds. The model for PRICE could not be estimated, and hence no results are reported.
Bold is used to indicate when the highlighted coefficient is constant i.e. when the upper and lower bounds of the confidence interval take the same sign.

Table 8
'special regressor' estimation results for Greenhouse gasses (*p-value in brackets).*

Performance measure:	Money metric performance measures (per employee)						Ratio based performance measures		
	SALES	EBITDA	PROFITS	OPROF	MCAP	ASSETS	PRICE	ROE	TOBQ
Level term	**N/A**	**0.1720**	**0.0119**	**0.0589**	**0.0090**	**0.0090**	N/A	**−2.8896**	**−109.4936**
		(0.00)	(0.09)	(0.06)	(0.03)	(0.00)		(0.00)	(0.01)
Squared term	**N/A**	**−0.0067**	−0.0004	**−0.0025**	−0.0001	**−0.0001**	**N/A**	**−0.0010**	**1.0481**
		(0.00)	(0.12)	(0.09)	(0.16)	(0.00)		(0.00)	(0.05)
Observations	2132	1931	2122	1940	2122	2132	2122	2122	2119

Note: SALES, EBITDA, PROFITS, OPROF, MCAP, ASSETS are in million British pounds. ROE in percentage terms, PRICE in British Pounds. The models for SALES and PRICE could not be estimated, and hence no results are reported.
Bold is used to indicate when the highlighted coefficient is constant i.e. when the upper and lower bounds of the confidence interval take the same sign.

Hypothesis 3, the evidence supports that voluntary disclosure does have some effect on the relationship between firm performance and emissions. Broadly speaking though, the evidence is not strong enough to suggest the EKC does not exist at the firm level.

Lastly, Tables 7 and 8 report estimation results for the 'special regressor' method that adopts the synthetic instrumental variables approach to handle endogeneity. The results from these additional regressions should perhaps be taken with a degree of caution. For both CO2 and GHG emissions, it is not possible to find a working specification when using PRICE as the performance measure. For GHG emissions it is also not possible to find a reasonable working specification when the performance measure is SALES. Notwithstanding these points, the results are largely supportive of the conclusions reported above. That is to say that the results reinforce the identified non-linear relationship.

For CO2 emissions, the 'special regressor' framework tends to reveal less confident results, with more insignificant coefficients than in the previous approaches, but for SALES and EBITDA performance measures, the non-linear effect is clearly visible. For GHG emissions on the other hand the evidence is more deeply compelling, suggesting strong significance for almost all variables scaled per-employee, and also for the performance measures defined in level terms. While the signs of the significant coefficients are consistent with those in the previous tables, the size of the effect can differ quite markedly. It would however be difficult to pin down with any concreteness whether the results in Tables 7 and 8 are in any manner superior to those in the previous tables, since they reflect a method controlling for different styles/sources of endogeneity.

Irrespective of some quantitative differences, the significance of the additional results in Tables 7 and 8 (as well as Tables 5 and 6) in validating or vilifying the previously suggested qualitative conclusions are beyond reproach. Efforts to try to dismiss the observed non-linear relationship between firm performance and emissions as being a statistical artefact arising from a failure to control for endogeneity have not proved successful. In this regard, the main contribution of this paper to test the hypothesis/existence of a potential corporate environmental Kuznets curve provides strong evidence in favour of its existence.

6. Summary and concluding remarks

The aim of this paper has been to examine the extent of UK firms' emissions reporting over the first decade of the 21st century and to test whether firm performance and emissions levels are related to each other. Additionally whether the kinds of functional relationships discussed in the empirical environmental literature have some validity at the firm level are considered. A wide range of performance measures are considered, to help validate the generality of the conclusions, as well as two definitions of emissions CO2 and the more encompassing measure of GHG. The measures are split into two types: money metric performance measures such as PROFITS or ASSETS, and ratio based performance measures such as ROE and TOBQ. A clear inverted U-shape is found when benchmarking against money metric based performance measures, while the evidence is less strong when using ratio based performance measures. These patterns are consistent across both types of emissions considered, albeit stronger for CO2 than GHG, and are also robust to possible biases that might arise from self-reporting.

To some degree the results pose questions regarding the role of environmental performance management and the possible conflict that may arise from environmental targets that can be potentially benchmarked against a range of alternative business performance measures. A more specific quandary emerging from the analysis, deserving of future study, relates to the apparent sensitivity of the results to money-metric versus ratio based measures of firm performance. TOBQ could arguably conflate several aspects of performance, making it more difficult for a stable result to emerge using this measure, but other ratios such as ROE are more difficult to defend. The results imply one of two things, either these performance measures share no relation with emissions, or on the other hand, maybe a relationship does exist, but is non-linear of a higher order than a simple inverted U-shape can handle. Both options are worth exploring further, though perhaps the former holds greater weight, since these two measures in particular are arguably more uniquely connected to the financial wealth of a firm, whereas the other performance measures more closely reflect, to a greater or lesser degree, the physical operations which will ultimately be the source of the emissions.

One limitation of this study resides in its partial focus. It would be interesting to try and say more regarding the economic significance and value of reporting, but this study explored only one side of the cost-benefit structure of the problem. More precisely the analysis here offers supporting evidence that the benefits of reporting do materially exist, albeit exhibiting some systematic non-linearities making the 'value' dampen under certain conditions. However there is no attempt to elaborate on the costs imposed/incurred from reporting. To this end, and like many studies preceding this one, only a partial picture of the topic is presented. Further research should do more to examine the cost implications. Only by accounting for the costs of reporting/audits/due diligence, as well as identifying the costs of emissions reduction activities, will it be possible to say with confidence something about the true economic value of reporting. Incidentally, and adopting a revealed-preference type view of the world, a simple logic argues that for reporting to occur, some value must exist, the main question should arguably then be about the size of the economic value, and not so much about its existence.

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