# How Voluntary Disclosers Respond to Mandatory Reporting: Evidence from Greenhouse Gas Emissions

**Jody Grewal**
*Rotman School of Management and Department of Management at University of Toronto and University of Toronto Mississauga*

**Abstract**

I study whether mandated reporting generates real effects for firms that already voluntarily disclose the mandated information. My setting is a regulation requiring firms to disclose greenhouse gas emissions (GHG). I find that firms voluntarily disclosing GHG prior to the regulation reduce GHG levels and intensity following mandated reporting. The change in a voluntary discloser's GHG ranking after mandated reporting predicts its subsequent GHG reductions. In addition, the GHG ranking of a voluntary discloser's industry predicts the firm's GHG reductions. These effects are stronger for firms that perceive higher reputational and regulatory risks from climate change. The results suggest that mandated reporting provides voluntary disclosers with information about first-time disclosers that allows them to (1) set competitive benchmarks and (2) preempt and/or prepare for future regulation. While prior research focuses on first-time disclosers, my study shows that among voluntary disclosers, mandated reporting can improve corporate social responsibility outcomes.

**Keywords:** *Corporate social responsibility; Disclosure regulation; Real effects; Greenhouse gas emissions; Climate change; Benchmarking*

**JEL classification:** D22; G18; G38; K32; M41; M48; Q54; Q58

# 1. Introduction

Mandated corporate social responsibility (CSR) reporting is a policy tool used to curb firms' socially undesirable behaviors. Recent studies show that firms providing new, improved, or more widely disseminated information after mandated CSR reporting improve their CSR outcomes. However, many firms voluntarily disclose CSR information absent regulation forcing them to do so. Whether mandated reporting changes the behaviors of those firms is an open question. To address this, I study a regulation in the United Kingdom (UK) requiring listed UK-incorporated companies to report greenhouse gas emissions in annual financial reports (hereafter, mandatory carbon reporting or MCR). A key feature of this setting is that some of the affected firms *already voluntarily disclosed* greenhouse gas emissions (GHG) prior to MCR. This allows me to examine the real effects of mandated reporting on voluntary disclosers and the channels through which mandated reporting shapes their behaviors.

To examine whether mandated reporting changes the behaviors of voluntary disclosers, I compare changes in GHG levels and intensity (GHG scaled by revenues) for treatment firms (UK-incorporated firms that voluntarily disclose GHG prior to MCR) to those of control firms (non-UK firms that voluntarily disclose GHG but are not affected by MCR) (see Figure 1). I account for flexible time and static firm-level differences through the inclusion of year and firm fixed effects and time-varying controls. I evaluate the comparability of GHG data reported before and after the mandate and address concerns that my results are confounded by reporting changes. I also validate that the pre-period trends of treatment and control firms are similar. Since events coinciding with MCR could still affect my inferences, I conduct a search for concurrent events and regulations and exclude firms with potential confounds from the analyses.

My first set of results suggests that disclosure regulation generates real effects among voluntary disclosers. I document a 11.8% decrease in GHG levels and a 11.7% decrease in GHG intensity after MCR for UK firms that voluntarily disclose their GHG prior to MCR, relative to firms outside the UK that voluntarily disclose GHG and are unaffected by mandated reporting. I separately examine the results for firms that disclose GHG data in financial reports prior to MCR and those that do not, and my evidence

shows that firm responses are not attributable to a disclosure channel change (Christensen, Floyd, Liu and Maffett 2017). To mitigate concerns that concurrent forces that both pressure UK firms to reduce GHG and push regulators to adopt MCR explain my results, I estimate a within-UK specification that uses private UK firms—which are not covered by MCR—as the control group. The inferences from this specification are similar to those of the main specification.

I then examine why mandated reporting generates real effects among voluntary disclosers. I make two predictions. The first is that when GHG data of previously non-disclosing firms become available, voluntarily disclosing firms that had good GHG performance (lower levels and intensity) relative to other voluntary disclosers before MCR, may learn that they are actually relatively poor performers, and therefore try harder to reduce GHG to protect their CSR reputations. I accordingly expect the change in a voluntary discloser's GHG ranking from before to after MCR to predict its post-MCR GHG reductions, a behavior which I call "competitive CSR benchmarking." Producing such a ranking, I find evidence that supports my prediction. I also find that the relation between worsening GHG rankings and larger subsequent GHG reductions is accentuated for firms that perceive higher reputational risks associated with their GHG, lending further support for the competitive CSR benchmarking explanation.

My second prediction is that MCR is a signal of costly future regulation such as carbon taxation, leading voluntary disclosers to reduce GHG to either preempt or prepare for such regulation. Since regulators typically impose such costs on carbon-heavy industries, I expect voluntary disclosers' assessments of future regulatory costs to depend on the GHG levels and intensities of their industry, revealed more fully when mandated reporting comes into effect. Thus, firms in industries with better (worse) GHG levels and intensities will have smaller (larger) responses to MCR. Here, the increased threat of regulation created by MCR interacts with expectations of the costs of regulation based on information provided by mandated reporting. Producing industry-rankings of GHG levels and intensities in the first year that MCR is in effect, I indeed find that voluntary disclosers in industries with higher GHG levels and

intensities have larger reductions following MCR. The result is stronger for firms that perceive greater regulatory risks from their GHG.

This paper contributes to research on the real effects of mandated reporting. This research studies how mandated financial reporting affects investment (e.g. Biddle, Hillary and Verdi 2009; Cheng, Dhaliwal and Zhang 2013; Cho 2015; Graham, Hanlon and Shevlin 2011; Shroff 2017) and how mandated CSR reporting affects CSR outcomes such as mine-safety violations (Christensen et al. 2017), payments to governments for mineral extraction rights (Rauter 2020), pollutants (Chen, Hung and Wang 2018), and GHG (Downar, Ernstberger, Reichelstein, Schwenen and Zaklan 2021; Jouvenot and Kreuger 2021; Tomar 2023). These works focus on firms that provide new, improved or more disseminated information, while largely ignoring firms that already voluntarily disclose the mandated information.[1] In contrast, I study whether real effects arise among firms that *already voluntarily* disclose prior to mandatory reporting. I predict and find evidence of an important input into voluntary disclosers' behaviors following mandated reporting: information revealed by previously non-disclosing firms. I find that this information is used by voluntary disclosers to (a) set competitive benchmarks and adjust behaviors to preserve CSR reputations and (b) form expectations of future regulation and adjust behaviors to preempt or prepare for it.

This study also adds to policy discussions concerning the effectiveness of CSR reporting mandates when a large number of firms already publish CSR information voluntarily. Despite widespread voluntary CSR reporting, policy makers increasingly use mandated reporting to affect firm behaviors in lieu of more explicit regulations that stipulate, prohibit, or tax firm behaviors and outputs. For example, the European Commission mandated CSR disclosures for European Union companies despite 67% of the affected firms already voluntarily disclosing CSR information (Grewal, Riedl and Serafeim 2019). In the US, the SEC is

[1] For instance, Chen et al. (2018) excludes firms that voluntarily disclosed before mandated reporting; their figures suggest voluntary disclosers comprise 35%–50% of the affected firms. Granja's (2018) sample includes state banks that voluntarily provided financial reports prior to the adoption of reporting requirements (around 35% of the affected firms), but he does not distinguish between these banks and non-disclosing banks. Gipper (2016) explains that firms provide varying levels of pay disclosure prior to CD&A disclosure requirements, but does not exploit this heterogeneity. One exception is Daske et al. (2008), which examines capital-market effects around the introduction of mandatory IFRS reporting among firms that voluntary adopted IFRS before it came into effect.

considering mandatory CSR reporting as part of its revision of Regulation S-K, despite 81% of the S&P 500 already voluntarily publishing standalone CSR reports.[2] My findings suggest that disclosure regulation can affect CSR outcomes even among voluntary disclosers.

Two papers examine the effects of MCR: Downar et al. (2021) and Jouvenot and Kreuger (2021). Downar et al. (2021) study UK firms disclosing GHG under another mandatory reporting rule (the European Union Emissions Trading Scheme or EU ETS) and document GHG reductions when these firms are required to shift GHG into financial reports under MCR. Jouvenot and Kreuger (2021) also examine firms disclosing under the EU ETS, along with firms disclosing voluntarily, and document GHG reductions. My paper differs along three key dimensions. First, I focus on voluntary disclosers, whereas Downar et al. (2021) and Jouvenot and Kreuger (2021) include mandatory disclosers in their analyses. Second, I identify and rule-out reporting changes as explanations for my results, whereas both papers attribute their results, in part, to reporting changes made by firms in response to MCR (for example, shifting GHG data into financial reports). Third, beyond the impact of MCR on GHG, I show that voluntary disclosers' efforts to reduce GHG depends on information revealed by previously non-disclosing firms, while both Jouvenot and Kreuger (2021) and Downar et al. (2021) focus on the financial performance effects of MCR. Thus, the evidence using different approaches is complementary and reinforces the inferences of our papers.

My study is similar to Daske, Hail, Leuz and Verdi (2008) and Tomar (2023). Daske et al. (2008) study capital-market effects around IFRS for firms that adopt IFRS for the first time and for firms that voluntarily adopted IFRS before the mandate. My study by contrast examines real effects—rather than capital-market effects—for voluntary disclosers. Tomar (2023) studies a GHG reporting program in the US and documents GHG reductions after affected facilities transition from non-disclosure to mandated disclosure of facility-level GHG on a government website. He predicts and finds that facilities learn about opportunities to improve energy efficiency from their peers' disclosures and use the newly available

[2] See the letter from the SEC Investor Advisory Committee: https://www.sec.gov/spotlight/investor-advisory-committee-2012/iac-approved-letter-reg-sk-comment-letter-062016.pdf.

information to set benchmarks. I also document peer benchmarking as a channel for GHG reductions; however, my findings suggest that firms learn about their competitive CSR positioning from rivals' disclosures and adjust behaviors to protect their CSR reputations. Thus, our studies are complementary and shed light on when different motivations to benchmark are more likely to affect firm behaviors following mandated reporting. For instance, when data is reported in a salient channel (such as financial reports) and presented at the aggregated firm-level (facilitating cross-company comparisons), competitive CSR benchmarking could explain firm responses, whereas when data is in a less-visible channel (such as a government website), and reported in a disaggregated manner for a subset of firm facilities (rendering cross-company comparisons infeasible)[3], benchmarking to infer energy efficiency opportunities may explain behaviors, as in Tomar (2023).

## 2. Background and Hypotheses

### *2.1 Background on MCR*

Mandatory Carbon Reporting was first proposed in 2008, when the UK Climate Change Act (the Act) was passed. Section 85 of the Act required the UK government to mandate the disclosure of GHG by April 2012 or explain to Parliament why it had not. The requirements under Section 85 received no press coverage and it was uncertain whether it would be enforced by regulation (Nitoiu 2013).

In November 2010, a report commissioned by the UK government on GHG reporting was released, describing how UK firms voluntarily disclosing GHG experienced benefits such as cost savings and improved relations with investors and customers (DEFRA 2010). In May 2011, the government published a consultation report proposing four options to achieve widespread and consistent GHG reporting. Only one of the options proposed enhanced voluntary reporting, while the other three options proposed mandatory reporting (DEFRA 2011). In March 2012, the government released a report outlining why no

[3] Tomar (2023) notes that only facilities located in the US and emitting over 250,000 tones of carbon dioxide equivalent are mandated to report, providing an incomplete picture of a firm's total emissions (Tomar 2023: p. 457).

regulations had yet been introduced, meeting the April 2012 deadline. The main reason cited was that the requirement to disclose might impose an unnecessary regulatory burden.[4] On June 20, 2012, the Deputy Prime Minister announced that listed UK-incorporated companies would have to report annual GHG for fiscal years ending on or after September 30, 2013 in the Directors' Report (the UK equivalent of SEC Form 10-K).[5] At the time, some UK firms were already covered by GHG reporting requirements and carbon programs, specifically the Carbon Price Floor, European Union Emissions Trading Scheme, Carbon Reduction Commitment, and Climate Change Levy. I describe these regulations and my approach to deal with them in Appendix B.

MCR requires companies to report the annual quantity of Scope 1 and Scope 2 GHG in metric tons of carbon dioxide equivalent resulting from the company's activities.[6] Firms must also disclose a ratio that expresses GHG in relation to a quantitative factor of the company's activities, such as sales or assets. MCR stipulates how GHG are to be calculated; see Section 4.4 and Appendix D for an explanation of MCR's requirements.

### *2.2 Hypotheses*

I examine whether disclosure regulation generates real effects among firms that already voluntarily disclose the mandated information (hereafter, voluntary disclosers). The answer to this question is unclear. Prior research attributes real effects of CSR disclosure regulation to the provision of new, improved, or more disseminated information (e.g. Chen et al. 2018; Dyreng, Hoopes and Wilde 2016). However, there are other theories linking regulation to the behaviors of voluntary disclosers. For one, heightened investor and stakeholder attention to GHG, due to MCR, could increase pressure on voluntary disclosers to reduce GHG.

[4] See: https://www.gov.uk/government/publications/company-reporting-of-greenhouse-gas-emissions.
[5] In the UK, Directors' Reports must be approved by the Board of Directors, reviewed by the auditor, and certified by the CFO and CEO; it is a criminal offense to report false or deceptive information.
[6] Scope 1 emissions are direct emissions from owned or controlled sources and Scope 2 emissions are indirect emissions from purchased energy that are a result of the reporting entity's activities but originate from sources owned or controlled by another entity. See *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard* https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf.

Research suggests that investors integrate GHG into stock valuation, but the lack of comparable data across firms is an impediment to its use (Amel-Zadeh and Serafeim 2018).[7] If MCR achieves its objective of widespread comparable GHG reporting across UK firms, it could increase the use of GHG data by market participants. Mandated reporting may also lead managers and investors to revise their expectations regarding the likelihood of future regulation that would impose direct costs on GHG, resulting in increased efforts to reduce emissions. Another possibility is that once mandated reporting forces all firms to disclose, voluntary disclosers—which previously used disclosure to distinguish themselves from non-disclosers—will seek to maintain a signal of good corporate citizenship with further GHG reductions. Alternatively, the revelation of information by firms disclosing for the first time may show voluntary disclosers that their efforts to reduce GHG are sufficient (or even excessive) in relation to their peers, resulting in no change—or even an increase—in their GHG. Given these opposing forces, the effect of MCR on GHG for voluntary disclosers is an empirical question. I therefore hypothesize:

**Hypothesis 1a**: *Voluntary disclosers reduce GHG following mandated reporting.*

### *2.2.1 Disclosure channel effect*

MCR requires GHG data to be disclosed in financial reports. Prior to MCR, some UK firms reported GHG data in financial reports, while others did not. Christensen et al. (2017) found that when US firms were mandated to shift mine safety data into financial reports, the heightened awareness of firms' safety records was the mechanism behind the observed reduction in safety incidents. Thus, it is possible that real effects in my setting are also attributable to a disclosure channel effect.

Ex-ante, it is unclear whether a shift of GHG data into financial reports will affect voluntary disclosers' behaviors. On the one hand, investors, financial analysts, and the news media may have become more aware of GHG data after MCR because financial reports are widely disseminated. But whereas the pre-regulation disclosure channel in Christensen et al.'s (2017) setting (the safety regulator's website) may

[7] Eccles et al. (2011), Griffin et al. (2017), and Matsumura et al. (2014) find that investors price corporate GHG.

have lacked visibility among investors and other stakeholders, the main pre-regulation disclosure channel in my setting is the Carbon Disclosure Project (CDP) survey, an initiative where over 500 institutional investors request that companies respond to a detailed questionnaire on climate change.[8] Firms publish CDP responses on their websites, Bloomberg provides CDP data to its subscribers, and banks, asset managers, pension funds, and insurers use CDP response data (SRI 2020).[9] Thus, in my setting, pre-period GHG data may be more salient. In addition, the pre-period data in Christensen et al. (2017) is presented at the mine-level; in the post-period, it is presented at the firm-level. The authors acknowledge that the data may be less usable in the pre-period, at least for unsophisticated users (e.g. CSR activists, NGOs) who could face difficulty mapping individual mines to parent companies; it is therefore possible that the data became more usable in the post-period. In my setting, by contrast, GHG data is presented at the firm-level in the pre- and post- periods. Given the differences between our settings, I hypothesize:

**Hypothesis 1b**: *Voluntary disclosers' GHG reductions are not driven by a disclosure channel change.*

### *2.2.2 Mechanisms*

Research suggests that a strong CSR reputation improves employee effort, retention, and motivation (Bode, Singh and Rogan 2015; Burbano 2019; Rupp, Shao, Thornton and Skarlicki 2013), customer loyalty (Albuquerque, Koskinen and Zhang 2019), and corporate resilience (Ding, Levine, Lin and Xie 2020; Lins, Servaes and Tamayo 2017) and makes it easier for firms to build trust and obtain resources from key stakeholders (Flammer 2018; Flammer and Luo 2017). Social irresponsibility, on the other hand, prompts activist NGOs, consumers, and investors to pressure firms to change their behaviors (e.g. Rauter 2020). With respect to the environmental aspect of CSR, firms with lower GHG have higher valuation (Matsumura

[8] Section 4.2 discusses my data sources, including CDP.
[9] According to a data usage specialist at Bloomberg, CDP data receives >100 hits per day. Moreover, investment teams from banks, asset managers, pension funds and insurers use CDP data in their analyses, and, in 2019, a group of 88 investors and 20 major activist groups targeted 700 companies for not being transparent about their environmental information through the CDP. See: http://www.sri-connect.com/index.php?option=com_content&view=category&layout=blog&id=211&Itemid=1987 and https://www.irmagazine.com/esg/investors-target-firms-over-failure-report-environmental-information

et al. 2014), better relations with employees, customers, and suppliers (Castelo Branco and Lima Rodrigues 2006; Simnett, Nugent and Huggins 2009), and greater insurance against stock price declines when the industry experiences an environmental disaster (Blacconiere and Patten 1994).

At the global level, scientists have quantified GHG reductions that are needed to limit global warming (IPCC 2018) but, at the firm level, there is little guidance on what constitutes "good" or "responsible" behavior. Absent guidance from regulators and experts, cross-company comparisons may emerge as a way for stakeholders to evaluate CSR performance and for firms to build their CSR reputations (Graafland et al. 2004). Consistent with this, benchmarking GHG performance across firms is used by the media (Shen 2017; Taylor and Watts 2019; Watts 2020), environmental NGOs (Dean 2017), government agencies (Pitt 2012), and investors (Durand, Paugam and Stolowy 2019) to identify which companies to target for "name and shame" campaigns and shareholder activism and, conversely, to recognize companies behaving responsibly (Taebi and Safari 2017; Tingley and Tomz 2020). Moreover, CSR ratings calculated and disseminated by data providers typically measure a firm's CSR performance in relation to best and worst performance across firms (Kotsantonis and Serafeim 2019).[10] Given the importance of reputation to differentiate a firm from its rivals, prior work theorizes that benchmarking could induce competition between firms on the basis of CSR performance (Graafland et al. 2004; Roberts and Dowling 2002); I call this phenomenon "competitive CSR benchmarking."

An implication of competitive CSR benchmarking is that new information that changes how a firm compares to its peers could affect its behavior. Because MCR provides new information about the GHG performance of previously non-disclosing firms, voluntary disclosers may find their relative GHG performance altered once MCR comes into effect. Concerned with maintaining their CSR reputations, they may then improve their own performance. It is also possible that if first-time disclosers reveal worse relative GHG performance, voluntary disclosers would ease GHG-reduction efforts—given that such efforts are

[10] In 2018, investors spent over $500 million on environmental, social and governance (ESG) ratings from data providers such as Bloomberg, MSCI, Thomson Reuters, and Sustainalytics (Gilbert 2019).

costly (Freiberg, Grewal and Serafeim 2021)—resulting in no change or even a drop in GHG performance after MCR. Yet another possibility is that first-time disclosers reveal GHG information that is consistent with voluntary disclosers' expectations and, because these expectations are built into extant GHG efforts, there will be no change to relative positions (or behaviors) following MCR.[11]

Alternatively, firms could infer from peers' disclosures that there are unexploited energy efficiency opportunities and seek these out. Consistent with this channel, Tomar (2023) finds that US facilities reduced GHG in proportion to their inefficiency ranking when they were mandated to report facility-level GHG for the first time. Regardless of whether benchmarking is used to exploit efficiency improvements or to protect CSR reputations, I predict that voluntary disclosers' responses to MCR will vary predictably on the basis of newly revealed GHG information from first-time disclosers.

**Hypothesis 2**: *GHG reductions are larger (smaller) for voluntary disclosers with worse (better) relative GHG performance following MCR.*

A second channel through which disclosure regulation may affect voluntary disclosers is the perceived threat of future regulation. Given that a number of jurisdictions, including Australia, Japan, Sweden and the state of California, mandated the disclosure of GHG prior to taxing corporate GHG, MCR could signal that the UK government intends to impose explicit costs on corporate GHG—for example, by carbon taxation—unless firms self-regulate.[12] Firms might therefore reduce GHG either to preempt future regulation or to be prepared for it.[13] While these behavioral changes could result from other regulations—whether or not they involve disclosure—mandated reporting provides complete information about listed UK firms' GHG and allows for sharper expectations to form about future regulatory costs. In particular,

[11] Expectations of GHG for non-disclosers could be formed on the basis of size or industry; however, according to the GHG Protocol, estimates of GHG are not particularly accurate. See: https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

[12] The escalation of transparency mandates to more explicit regulation has occurred in other contexts. For instance, mandating disclosure of payments to foreign governments provided impetus for the US Foreign Corrupt Practices Act, which brought criminal penalties for violations. Another example is mandated disclosure of mining accidents to the US Mine Safety and Health Administration, which was followed by requirements for regular mine inspections and penalties for safety violations.

[13] Maxwell et al.'s (2000) model implies that the threat of government regulation induces firms to reduce pollution.

because regulators typically impose carbon costs on *industries* with poor GHG performance (Nachmany, Fankhauser, Setzer and Averchenkova 2017), voluntary disclosers in industries with worse GHG performance may expect higher future regulatory costs and, accordingly, respond more strongly to MCR.[14] Here, the increased threat of regulation created by MCR interacts with expectations of the costs of such regulation based on complete information about GHG provided by mandated reporting. Therefore, I predict that a voluntary discloser's GHG reductions will depend on the relative GHG performance of the firm's industry once all firms are mandated to report GHG. I hypothesize:

> **Hypothesis 3**: *GHG reductions are larger (smaller) for voluntary disclosers in industries with worse (better) relative GHG performance following MCR.*

## 3. Research Design

The objective of this study is to measure the causal effect of MCR on GHG, where the unit of analysis is a firm. My empirical strategy relies on the institutional fact that only UK-incorporated, publicly listed firms (on the Main Market of the LSE, NYSE, or NASDAQ) are subject to the mandate and hence only these "treated" firms are required to disclose GHG.[15] After removing non-UK firms with confounds (see Section 3.1), I use a difference-in-differences approach to compare changes in GHG for treatment and control firms before and after the passage of the regulation and estimate the following model over my sample period 2004–2019:

$$Y_{it} = \alpha_i + \lambda_t + \beta_1 Treat_i \times Post_t + \sum \beta_{it} \text{controls} + \varepsilon_{it}\,, \qquad (1)$$

where $Y_{it}$ is *GHG_Level*, the natural logarithm of GHG (in metric tons of carbon dioxide equivalent) or *GHG_Intensity*, the natural logarithm of the ratio of GHG to revenues (in USD). $\alpha_i$ refer to firm fixed effects

[14] In a study of climate change-related regulations around the world, Nachmany et al. (2017) note that such regulations are rarely applied to all firms in a jurisdiction (owing to costly administration) or to targeted companies (owing to actual or perceived competitive disadvantages), but are most often applied to particular industries.

[15] The legislation exempts certain (small) firms from the reporting requirement, defined as firms that meet at least two of the following requirements: (a) turnover lower than GBP 6.5m, (b) balance sheet total lower than GBP 3.26m, and (c) average number of employees lower than 50. Given that firms that list on LSE's main market are mostly large, few come close to these thresholds.

that absorb all observed and unobserved time-invariant firm characteristics and $\lambda_t$ refer to year fixed effects that control for common macroeconomic shocks across firms. I run alternate specifications including time-varying financial controls (size, profitability, price-to-book ratio, leverage, capital intensity, and sales growth) and time-varying country controls (carbon intensity of the electrical grid and gross domestic product, which help account for country-specific shocks to carbon intensity and demand, respectively) defined in Appendix A.[16] Financial variables are from Bloomberg and measured in USD.

The average treatment effect is the estimated $\beta_1$ coefficient on the interaction $Treat_i \times Post_t$, which captures the change in $Y_{it}$ for treatment firms after the regulation relative to the change for control firms. $Post_t$ is an indicator equal to one in years 2013–2019 and $Treat_i$ is an indicator equal to one if the firm is covered by the regulation and does not have any confounds, and zero otherwise. The assumption of this model is that $Treat_i$ is uncorrelated with all unobservables (the error term, $\varepsilon_{it}$). However, there could be differences across treatment and control firms that bias the estimate of $\beta_1$. It is also possible that regulators passed the law knowing that UK firms would reduce emissions in the post-period regardless of the mandate, which would bias $\beta_1$ downwards. In the following sections I explain how I address these concerns.

### *3.1 Confounding Events*

My analysis involves comparing UK to non-UK firms. I must therefore account for regulations and events, within and outside the UK, that could confound my inferences. Appendix B summarizes GHG-regulations (disclosure, carbon taxation, and cap-and-trade schemes) that passed or came into effect during the sample period and my approach to deal with them.

First, I identify potential confounds *outside* the UK, and exclude certain firms from the pool of control firms; see Internet Appendix Table II for a description of these potential confounds. In particular, I

[16] In order to report the GHG associated with a firm's activities, the Greenhouse Gas Protocol and other international reporting standards require firms to convert activity data such as distance travelled, liters of fuel consumed, and electricity used into carbon emissions using country-specific conversion factors. These rates differ between countries and over time due to the carbon-intensity of the energy grid (e.g., electricity generation by coal is more carbon-intensive than that generated by natural gas, so the emissions factors reflect this). I include, as a control variable, the average carbon-intensity of the electrical grid across all regions in a given country for which data is available.

exclude firms from countries where GHG regulations passed during the sample period (2004–2019) because these regulations are likely to differentially affect the GHG of these firms relative to UK firms (and thus they do not serve as appropriate counterfactuals for UK firms). This leads me to exclude firms from Australia, Bulgaria, Chile, Colombia, Ireland, Japan, New Zealand, Singapore, South Africa, South Korea, Switzerland, and the United States. Second, I identify potential confounds that could affect GHG of firms *within* the UK, such as cap-and-trade schemes, carbon taxes, and reporting programs. I search the UK Government Department for Environment, Food and Rural Affairs (DEFRA) website for policies, publications, consultations, and announcements relating to GHG. I summarize potential UK-based confounds, as well as my approach to dealing with them, in Appendix B.[17]

### *3.2 Parallel trends*

Model (1) uses a standard difference-in-differences framework. The key assumption of this model is that the control group's mean outcome changes are a valid counterfactual estimate for the treatment group's mean outcome changes, if the regulation had not occurred. Although this assumption cannot be tested directly, I plot treatment effects in event time in Figures 2 and 3 to assess if pre-period trends in *GHG_Level* and *GHG_Intensity* are similar for the two groups. I find that the coefficients of *Treat* x *Post* are close to zero and statistically insignificant leading up to MCR, suggesting that the parallel trends assumption is not violated.

## 4. Data and Sample

### *4.1 Sample construction*

Table 1 outlines the sample construction. The starting treatment sample consists of all 2,530 securities listed on the London Stock Exchange as of June 30, 2012. I remove Alternative Investment Market shares not subject to the regulation (1,171), depository receipts, fixed-interest securities, and warrants (339), firms not

[17] In untabulated analyses I find that my inferences are unaffected if I remove countries where broad (i.e. non-GHG-specific) CSR disclosure regulations passed within two years of MCR, specifically Brazil, France, India, Norway and Taiwan.

incorporated in the UK (106) and equity investment instruments, REITs, holding companies and trusts (349). This leaves 565 UK companies covered by the regulation. After removing UK firms with confounds (37), missing or insufficient GHG data prior to MCR (332), and inconsistent GHG reporting around the passage of MCR (46), I am left with 150 UK firms.[18] Following a similar process, I obtain 281 non-UK firms that do not have confounds or inconsistent GHG reporting. This results in a sample of 431 firms and 4,387 firm-years.

### *4.2 GHG data sources*

My sources for GHG data depend on where firms disclose GHG information. First, I check financial reports, followed by the Carbon Disclosure Project (CDP) survey database (discussed below) and, if necessary, CSR reports. I identify 64 UK firms and 93 non-UK firms that disclose GHG data in financial reports prior to MCR, and 86 UK firms and 188 non-UK firms that disclose GHG in response to the CDP survey (but not in their financial reports) prior to MCR. After MCR is in effect, I collect GHG data from UK firms' financial reports; for non-UK firms, I first check financial reports, then the CDP survey database.

The Carbon Disclosure Project (CDP) is an annual survey which requests climate change information from large companies on behalf of over 500 institutional investor signatories and supply chain members. Response rates are typically high. For example, in 2019, 93% of the Global 500 responded. The CDP is the first survey to provide large-scale information about climate change risks, opportunities, policies, and performance across firms, and is also the primary data source for other data providers that aggregate information on firms' environmental performance (Ioannou et al. 2015). The primary questions I use from the CDP survey are: "Please provide your gross global Scope 1 emissions figure for the reporting year in metric tonnes CO2e" and "Please provide your gross global Scope 2 emissions figure for the reporting year in metric tonnes CO2e."[19]

[18] I require that firms have at least three years of GHG data in the pre-period (2004–2012); fewer than that is insufficient to establish time-trends in the pre-period, which is necessary to validate the parallel trends assumption.
[19] CDP sends out its annual survey in October, and asks companies to respond by the end of May (per CDP, responses can be updated until mid-August). Companies complete the survey using CDP's Online Response System,

### *4.3 GHG intensity ratio*

Under MCR, firms must report annual GHG and a ratio that divides annual GHG by an activity measure; for example, metric tons of $CO_2$ equivalent *per unit of revenue* or metric tons of $CO_2$ equivalent *per metric ton of product*. While firms are free to choose their activity measure, the same measure must be used year over year. However, intensity ratios are not comparable across firms unless they share the same activity measure. Therefore, I divide annual GHG by annual sales revenue in USD.[20] I select sales revenue as the activity measure for two reasons. First, the CDP asks firms to report an intensity ratio that normalizes GHG by sales revenue.[21] Thus, I have an intensity ratio that is disclosed before and after MCR and is comparable across firms. Second, using an activity measure that has been audited, as opposed to one that has not (such as floor space or number of full-time employees), increases confidence in the ratio's reliability.

### *4.4 Comparability of GHG reporting before and after MCR*

It is critical to establish whether GHG reporting in the pre-period (that is, before MCR came into effect, or years 2004–2012) is comparable to GHG reporting in the post-period (that is, after MCR came into effect, or years 2013–2019). Because MCR imposes new requirements, UK firms may change their reporting to comply. Non-UK firms may also see reason to change their reporting. In either case, the interpretation of the results could be confounded.

To identify reporting changes, I refer to the UK government's regulatory guidance for a complete list of MCR's requirements (DEFRA 2012). MCR's requirements were formulated using the GHG Protocol Corporate Accounting and Reporting Standard (the "GHG Protocol"), an internationally recognized

found on CDP's website. CDP requires that a member of the firm's executive committee signs-off on the survey response prior to its submission to CDP.

[20] Because the treatment sample consists of UK firms while the control sample consists of non-UK firms, I use sales revenue in USD (from Bloomberg) to ensure consistency across firms.

[21] The CDP survey question is: "Please state your intensity figure as gross combined Scope 1 and 2 emissions for the reporting year in metric tons of carbon dioxide equivalent per unit total revenue."

framework that guides companies on material GHG reporting elements.[22,23] My comparison of MCR's requirements and the GHG Protocol, as well as my discussions with two associates from the GHG Protocol, suggest that MCR's requirements cover all of the reporting elements in the GHG Protocol. I therefore use MCR's requirements and track how each firm in my sample discloses its GHG in each year of the sample period, in order to identify whether material reporting changes were made around MCR.

In Appendix D, I tabulate the reporting elements, MCR's requirements, the number of firms that changed their reporting around MCR, and my strategy to deal with potential confounds. I identify 46 UK and 94 non-UK firms that changed their reporting methodology, boundary, period, or scope (note that the totals in Appendix D exceed 46 and 94 because some firms made more than one change); I remove all of these firms from the sample to prevent them from confounding the results. Of the 150 UK firms in my sample, 86 shifted GHG data into financial reports after MCR; in Section 5.3, I assess whether this presents a confound and my results suggest that it does not. In Section 5.3, I also assess whether MCR's recommendation to obtain assurance presents a confound and do not find that this is the case.

### *4.5 Descriptive statistics and correlations*

Table 2 presents summary statistics for the sample, and Table 3 presents the correlation matrix for variables used in the main analyses. As expected, *GHG_Level* is strongly positively related to total assets, which is consistent with prior literature documenting that carbon emissions are proportional to firm size (e.g., Ioannou et al. 2015). In particular, *GHG_Level* has a correlation with *Assets* of 0.39. *GHG_Level* is also positively correlated with capital expenditures scaled by revenues (*Capex*) at 0.25, and negatively correlated with price-to-book ratio (*PTB*) at -0.10. *GHG_Intensity* is positively related to *GHG_Level* (at 0.36), *Capex*

[22] According to the GHG Protocol, information is considered material if, by its inclusion or exclusion, it influences users' decisions or actions. The GHG Protocol can be accessed here: https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf.

[23] GHG Protocol is the most widely used and internationally recognized greenhouse gas accounting standard. It has been adopted by the California Climate Action Registry, the World Economic Forum Global Greenhouse Gas Registry, and national programs such as the US Environmental Protection Agency Greenhouse Gas Reporting Program and the Tokyo Emissions Scheme. The vast majority of listed companies that report greenhouse gas emissions follow the GHG Protocol. See: https://ghgprotocol.org/about-us.

(at 0.19) and *GridCarbonIntensity* (at 0.11). Correlations between the financial control variables are in line with expectations. Table 4 shows country representation across the sample. Control firms are well distributed, with no more than 20% coming from a single country.

# 5. Baseline Results

### *5.1 Effect of MCR on GHG*

Panel A of Table 5 presents estimates of regression Model (1) using *GHG_Level*, the natural logarithm of greenhouse gas emissions in metric tons of carbon dioxide equivalent for firm *i* in year *t*, as the dependent variable. Standard errors are clustered by industry. Across the specifications—which differ depending on the inclusion of firm fixed effects, year fixed effects, and time-varying firm controls—the coefficient estimates on *Treat* x *Post* are negative and statistically significant at the 5% level or better. The estimates reveal that treatment firms reduced GHG by 11.6% to 31.2%, on average, in response to MCR.[24] In Column 3, the specification that includes firm and year fixed effects and time-varying controls, the estimated average treatment effect is a reduction in GHG of 11.8% (significant at the 1% level).[25] In Panel B of Table 5, I estimate Model (1) with *GHG_Intensity* (the natural-log transformed ratio of GHG to revenues) as the dependent variable. The estimates on *Treat* x *Post* are negative across all specifications and statistically significant at the 1% level. Column 3 reports results for the specification that includes firm- and year- fixed effects along with time-varying controls; the estimate indicates that MCR reduced GHG intensity by 11.7%.

To minimize differences in observable characteristics across treatment and control firms, I construct a matched sample using propensity scores. I match on *GHG_Level, Assets, ROA, PTB, Leverage, Capex* and *SalesGrowth* in 2012, the year before MCR came into effect. I also include the six-digit Global Industry Classification System (GICS) code in the matching algorithm, due to emissions being, in part, a

[24] For instance, the estimate on *Treat* x *Post* in Column 1 is -0.374, therefore (1-exp(-0.374)*100) = 31.2%.
[25] The economic magnitude of this result is reasonable compared to prior work. Tomar (2023) documents GHG reductions of 7.9% following mandatory disclosure, Downar et al. (2021) document GHG reductions of 14-18%, and Jouvenot and Kreuger (2021) document GHG reductions of 16%.

function of industry activities (Doshi et al. 2013). I use single nearest-neighbor propensity score matching without replacement within a specified caliper width, yielding a matched sample of 79 treatment firms and 79 control firms.[26] Panel A of Table 6 reports means for the treatment and control firms, and a *t*-statistic from regressing each covariate on $Treat_i$, and illustrates how matching improves balance in the means of the covariates. Matching produces balance for all measures, apart from *ROA*; I include time-varying firm controls, including *ROA*, in the regressions to account for any remaining differences. Figures 4 and 5 plot treatment effects in event time for the matched samples, providing graphical evidence that the parallel trends assumption is not violated.

Panels B and C of Table 6 report estimates of the effect of MCR on GHG levels and intensity, respectively, for the matched sample. The coefficients of interest are negative and significant at the 10% level or better. The estimates when including firm and year fixed effects and time-varying controls indicate a decrease in *GHG_Level* of 11.8% (Panel B, Column 3) and a decrease in *GHG_Intensity* of 15.4% (Panel C, Column 3). Overall, the results for the matched sample confirm the inferences drawn for the full sample.

### *5.2 Additional analyses to address endogeneity concerns*

An important threat to identification is that the timing of MCR could be non-random, such that it coincides with other forces that pressure UK firms to reduce GHG and also push UK regulators to adopt climate change regulation. It is also conceivable that voluntary disclosers are precisely the firms that would be most affected by these concurrent forces and that such forces could therefore lead both to the adoption of MCR in the UK and to changes in firm behavior. Because the control sample used in the prior analyses consists of non-UK firms, the estimates could be biased as a result of omitted UK-specific factors.

To address these concerns, I conduct a within-UK analysis that uses private UK-incorporated firms as the control group (private firms are not covered by MCR). Using the CDP database, I identify 45 private

[26] I used a caliper width of 0.1 times the pooled standard deviation of the logit of the propensity score (Rosenbaum and Rubin 1985).

UK companies that report comparable GHG data before and after MCR (following the process described in Section 4.4) and that are not affected by concurrent GHG regulations in the UK (following the process described in Section 3.1). Panel A of Table 7 reports covariate means in 2012 and *t*-statistics for the differences between the two samples; none of the differences are statistically significant.[27] Figures 6 and 7 provide graphical evidence that the pre-period trends are parallel, suggesting that private UK firms provide a reliable estimate of the counterfactual trend that public UK firms would follow, if not for MCR.

Panels B and C of Table 7 present estimates of Model (1) for the within-UK sample, using *GHG_Level* as the dependent variable in Panel B and *GHG_Intensity* in Panel C. Because some industries in this smaller sample only have a few observations, I cluster standard errors by firm (rather than by industry), to avoid small cluster bias (Bertrand, Duflo and Mullainathan 2004). In Panel B, the estimate in column 3 (when including firm and year fixed effects, and time-varying controls) shows a decline in *GHG_Level* of 20.5%, and the analogous estimate in column 3 of Panel 3 shows a decline in *GHG_Intensity* of 17.1%.

These findings are consistent with the baseline results reported in Table 5 showing that MCR led to lower GHG and GHG intensity. There are, however, limitations to this within-UK analysis. For one, my assumption that the two groups respond similarly to forces that influence GHG behavior and regulation may not be valid. I cannot directly test this assumption; however, the similarity of the trends in GHG levels of the two groups leading up to MCR (shown in Figures 6 and 7) helps validate it. Another limitation is that private UK firms may anticipate future mandated reporting, resulting in a pre-emptive response to MCR that would violate the Stable Unit Treatment Value Assumption, which assumes that one firm's outcomes are unaffected by another firm's treatment assignment. However, a spillover effect of this nature would likely bias *against* the treatment effect and understate the results shown in Table 7. Therefore, the benefit

[27] Fewer covariates are shown because price-to-book, capital expenditures and sales growth are scarcely populated or unavailable in Bloomberg for private firms, while GDP and grid intensity are the same at the country-year level.

of this within-UK analysis—addressing omitted-variable concerns relating to the nonrandom timing of MCR—outweighs these limitations.

I also perform robustness tests (using an EU-only sample and alternative dependent variables) relating to the main results and find that my inferences are unchanged. The results are reported and discussed in Internet Appendix Table I.

### *5.3 Change in disclosure channel and assurance*

MCR requires GHG data to be reported in annual financial reports. As noted in Section 4.2, prior to MCR 64 UK firms (93 non-UK firms) disclosed GHG information in financial reports and 86 UK firms (188 non-UK firms) disclosed it to the CDP survey. Thus, the results in Tables 5-7 could be driven by the firms that shift GHG data into financial reports as a result of MCR, consistent with the findings in Christensen et al. (2017).[28]

To test whether a change in disclosure channel drives my results, I estimate Model (1) separately for firms disclosing GHG data voluntarily in their financial reports prior to MCR ("financial-report disclosers") and firms disclosing GHG data outside of financial reports prior to MCR ("non-financial-report disclosers"). Columns 1 and 2 of Table 8 report results for the financial-report and non-financial-report disclosers, respectively, using *GHG_Level* as the outcome variable. The coefficients show that financial-report disclosers reduced GHG levels by 25.4%, while non-financial report disclosers reduced GHG levels by 20.9%. Importantly, the estimates for financial-report disclosers and non-financial-report disclosers are similar: the coefficients on *Treat* x *Post* in Columns 1 and 2 are statistically indistinguishable (*p*-value = 0.509). This suggests that the effects of MCR are similar across firms that report GHG in financial reports or elsewhere prior to the law, which is inconsistent with a disclosure channel effect.

[28] The disclosure channel is generally stable for non-UK firms, with only 11 non-UK firms shifting GHG data into financial reports in the post-period; my inferences are unchanged if these firms are excluded from the analyses.

It is also unclear whether MCR's recommendation for firms to obtain assurance over GHG confounds my results. In addition, there is the possibility that my results are driven by firms that misrepresent their GHG. To assess both issues, I split my sample into firms that receive assurance over GHG ("assurance firms") and firms that do not ("non-assurance firms") and examine the effects of MCR separately for the two subsamples. To do this, I search for GHG assurance information in CDP responses, financial reports, and CSR reports. I assume the firm does not receive assurance if I cannot find this information. The CDP survey questions I use are "Please indicate the assurance status that applies to your reported Scope 1 and 2 emissions" and "Attach the assurance statement if applicable." I designate firms as "assurance firms" if they (a) select "Third-party assurance" as their response and (b) provide an assurance statement from a third-party source. I identify 85 UK firms and 170 non-UK firms that obtain assurance from at least 2011 onwards and 65 UK firms and 111 non-UK firms that do not.

The results are tabulated in Columns 3 and 4 of Table 8. The treatment effects are negative and significant and—importantly—similar across the assurance and non-assurance samples; in particular, the treatment effects are statistically indistinguishable ($p$-value = 0.42). This suggests that the GHG reductions were not driven by misrepresentations or a shift to assurance around MCR.

# 6. Mechanisms: How Does MCR Affect GHG?

My previous analyses show that voluntarily disclosers reduce GHG levels and intensity following MCR. In this section, I explore potential channels through which mandated disclosure could affect behaviors.

### *6.1 Competitive CSR benchmarking*

Hypothesis 2 predicts that when GHG information about previously non-disclosing firms becomes available, voluntarily disclosing firms that had good relative GHG performance (that is, relatively low GHG) before MCR may learn that they are now relatively poor performers and decide to further reduce GHG to protect their CSR reputations.

To measure relative GHG performance before MCR, I follow Tomar (2023) and normalize the unlogged values of *GHG_Level* to create a ranking across UK firms that voluntarily disclose GHG data in 2012, such that the highest-emitting firm in 2012 is assigned a value of 1 and the lowest-emitting firm is assigned a value of 0. To rank firms after MCR, I normalize unlogged *GHG_Level* in 2013 (the first year that MCR was in effect) across all UK firms covered by MCR. Then, I compute the ranking change as the difference between the normalized value after MCR minus the normalized value before MCR. A positive difference indicates that a voluntarily disclosing firm has a worse ranking (and is a relatively higher emitter) once the GHG information of previously non-disclosing firms becomes available, while a negative difference indicates that an already-disclosing firm has a better ranking (and is a relatively lower emitter).

I estimate the following OLS regression model:

$$ln(\Delta GHG\_Level)_i = \alpha_1 \Delta GHG\_Ranking_i + \sum \alpha_i \Delta \text{controls} + \varepsilon_{it} \qquad (2),$$

where the dependent variable is the logged change in firm *i*'s absolute emissions from the pre-MCR period (2004–2012) to the post-MCR period (2013–2018), and *ΔGHG_Ranking* represents the change in the firm's absolute emissions ranking (described above). I include the same set of control variables as in Tables 5-8 and compute changes from pre-period to post-period average values. $\alpha_1$ estimates the change in emissions for voluntary disclosers; Hypothesis 2 predicts a negative $\alpha_1$ consistent with voluntary disclosers with worse relative GHG after MCR reducing their GHG more. Because, for this model, there is one observation per firm, I omit firm and year fixed effects and cluster standard errors by industry.

Table 9 presents the results. The coefficient on *ΔGHG_Ranking* in Column 1 is negative and significant at the 5% level (coef. = -0.087 *t*-stat = 2.68), indicating that the worse a voluntary discloser's ranking is in 2013 (the first year that MCR is in effect) relative to the firm's pre-MCR ranking, the more it reduces its GHG.

Hypothesis 2 is predicated on the assumption that firms respond to worsening GHG rankings through their desire to maintain a strong CSR reputation relative to their peers, which I call competitive

CSR benchmarking. Another possibility is that firms infer opportunities to improve their energy efficiency from peers' disclosures (Tomar 2023). In my setting, competitive CSR benchmarking is more likely for the following reasons. First, MCR requires data to be reported in financial statements which could be more salient to external stakeholders than the government website in Tomar's (2023) setting, and therefore more likely to invoke competitive benchmarking. Second, MCR requires GHG data to be reported at the firm-level, which is conducive to competitive benchmarking because it allows for easier cross-company comparisons. By contrast, the facility-level data in Tomar's (2023) may be difficult to aggregate to the firm-level (especially for unsophisticated users such as environmental activists and NGOs) and even if the data can be aggregated, only a subset of a firm's facilities are required to report emissions, hindering across-firm comparisons. Rather, as Tomar (2023) argues, the data in his setting are "granular and informative about operations" in ways that aggregated, firm-level data are not (Tomar 2023: p. 453), allowing firms to identify unexploited energy efficiency opportunities from their peers' disclosures.

To test my conjecture, I examine whether responses to worsening GHG rankings are stronger if firms perceive higher climate change-related reputational risks. The rationale is that if relative performance changes following MCR affect behaviors through the desire to avoid reputational damage, responses should be stronger among firms with greater reputational concerns associated with their GHG. I use CDP responses about climate change risk perceptions; in particular, the survey asks firms whether they perceive reputation, regulatory, physical, and other risks to their business that are driven by climate change.[29] For each risk selected, firms use drop-down menus to assess the likelihood that the risk will materialize, the magnitude of its impact, and the timeframe over which it will materialize. For instance, a UK-incorporated plumbing and heating products distributor responded in 2012 that it perceives the reputational risk to its business driven by climate change as being "more likely than not" (the *likelihood* question), having a "medium-high" impact (the *magnitude* question), and materializing in "1 to 3 years" (the *timeframe* question). In its

[29] Firms are asked "Have you identified risks to your business that are driven by climate change? Tick all that apply." Firms can select "Risks driven by regulation," "Risks driven by physical climate parameters," "Risks driven by reputation," and "Other." Firms are also asked to provide a brief description of the risk(s) selected.

survey response, the company described its climate change reputation risk as follows: "The management of climate change issues is increasingly becoming a key consideration of investors during their decision making process. Having a poor reputation in relation to climate change management could potentially affect access to finance or impact our share price. It could also adversely affect our relations with customers, suppliers, exchange partners and employees. We must be able to provide a clear and robust response to investor and stakeholder enquiries relating to our management of carbon emissions and other climate change risks and opportunities."

I construct a measure of climate change reputational concerns using CDP responses from 2012, the year immediately before MCR came into effect.[30] I convert categorical responses to the reputation risk questions into numerical form as follows: For the *likelihood* question, firms that select *Exceptionally unlikely* and *Unknown* are assigned a likelihood value of 1; *Very unlikely* = 2; *Unlikely* = 3; *About as likely as not* = 4; *More likely than not* = 5; *Likely* = 6; *Very likely* = 7; and *Virtually certain* = 8. For the *magnitude* question, firms that select *Low* are assigned a magnitude value of 1; *Low-medium* = 2; *Medium* = 3; *Medium-high* = 4; and *High* = 5. For the *timeframe* question, firms that select *Over 10 years* or *Unknown* are assigned a timeframe value of 1; *6 to 10 years* = 2; *3 to 6 years* = 3; *1 to 3 years* = 4; *Up to 1 year* = 5; and *Current* = 6. I take the product of the likelihood, magnitude, and timeframe values to create a composite measure of climate change reputation risk, or *ReputationRisk* (see Appendix A).

Column 2 of Table 9 reports results when estimating a variation of Model (2) using *ΔGHG_Ranking* x *ReputationRisk* as the independent variable of interest and controlling for both *ΔGHG_Ranking* and *ReputationRisk*. The negative and significant coefficient (at the 5% level) on *ΔGHG_Ranking* x *ReputationRisk* (coef. = -0.043, *t*-stat = 2.26) shows that the relation between worsening GHG-level rankings and larger subsequent GHG reductions is accentuated for firms that perceive greater climate-change related reputational risks.

[30] Specifically, I use CDP response data provided by firms before May 2012 to ensure that the risk responses are not obfuscated by MCR, which was announced in June 2012.

Taken together, the results suggest that the change in a voluntary discloser's GHG ranking from before to after MCR predicts its subsequent GHG reductions. While this could lend support to either the competitive CSR benchmarking prediction in Hypothesis 2, or to firms inferring unexploited energy efficiency opportunities (Tomar 2023), I find that the relation between worsening GHG rankings and larger GHG reductions is *stronger* for firms that have higher climate change-related reputational risks, which shifts the weight of the evidence towards competitive CSR benchmarking. As noted earlier, this is in-line with GHG data in my setting being disclosed at the firm-level and in financial reports, which is more likely to facilitate across-company comparisons by stakeholders and provoke competitive CSR benchmarking responses by firms.

### *6.2 Regulatory costs*

Another potential mechanism is that mandated reporting signals to firms that regulation to impose explicit costs on GHG is forthcoming, while also revealing GHG data about previously non-disclosing firms, which allows voluntary disclosers to form expectations about the likelihood of industry regulation. Hypothesis 3 predicts that voluntary disclosers' expectations of future regulatory costs depends on the GHG levels and intensities of their industry revealed by mandated reporting, such that firms belonging to industries with better (worse) GHG levels and intensities will have smaller (larger) responses to MCR. Because regulators have used mainly used GHG levels to justify imposing carbon costs on certain industries (Nachmany et al. 2017), I expect firms to incorporate GHG levels into their assessments of future regulatory costs.

To measure relative industry GHG performance, I compute the average unlogged *GHG_Level* in 2013 (the first year that MCR was in effect) across all firms in an industry and normalize this value to create a ranking so that all firms in the industry with the highest average GHG level in 2013 are assigned a value of 1 and those in the industry with the lowest average GHG level in 2013 are assigned 0.

I estimate a variation of Model (2) using *Industry_GHG_Ranking*, described above, as the variable of interest. I predict a negative $\alpha_1$, consistent with firms in industries with relatively high GHG levels

reducing their GHG levels more than firms in industries with relatively low GHG levels, consistent with the former expecting higher regulatory costs associated with their GHG and responding with behaviors to preempt or prepare for such regulation.[31]

The results are presented in Columns 3 and 4 of Table 9. The negative and significant coefficient on *Industry_GHG_Ranking* in Column 3 (coef. = -0.053, *t*-stat = 4.03) reveals that voluntary disclosers in industries that had high relative GHG levels in 2013 reduce GHG more in the post-MCR period. The evidence is consistent with Hypothesis 3 and suggests that higher expected regulatory costs is a channel through which MCR generates behavioral changes in voluntary disclosers.

Hypothesis 3 assumes that voluntary disclosers anticipate regulatory costs associated with their GHG. Although it is difficult to test this assumption directly, I expect that if industry ranking affects firm behavior after MCR through the desire to pre-empt or prepare for future regulation, GHG reductions should be larger for firms that perceive higher climate change-related regulatory risks. To test this, I use CDP response data from 2012 and follow the same process described in Section 6.1 to measure reputational risk; this time, I use responses concerning regulatory risks to the respondent's business. For instance, a UK consumer packaging company responded in 2012 that it perceived the regulatory risk to its business driven by climate change as being "more likely than not" (the *likelihood* question), having a "medium-high" impact (the *impact* question), and materializing in "3 to 6 years" (the *timeframe* question). In its survey response, the company described its regulatory risk as follows: "Carbon taxes and efficiency regulations could adversely affect our operational costs, procurement costs and compliance costs which will result in lower profits or high costs being passed through to our customers and ultimate consumers."

[31] The specification choices are the same as those in Columns 1 and 2 of Table 9; in particular, the omission of firm and year fixed effects (because there is one observation per firm) and clustering of standard errors at the sector level.

I convert categorical responses to the regulatory risk questions into numerical form following the method outlined in Section 6.1. I take the product of the likelihood, magnitude, and timeframe values to create a *RegulationRisk*, a composite measure of climate change regulatory risk (see Appendix A).

I estimate a variation of Model (2) using *Industry_GHG_Ranking* x *RegulationRisk* as the independent variable of interest. In Column 4, the coefficient estimate on the interaction term is negative and statistically significant at the 1% level. The estimate of -0.053 (*t*-stat = 4.37) indicates that the negative relation between a firm's industry ranking on *GHG_Level* and its subsequent GHG reductions is stronger for firms that perceive greater regulatory risks associated with their GHG.

These results support Hypothesis 3 and the interpretation that voluntary disclosers reduced their GHG levels to preempt or prepare for future regulation. Specifically, MCR increased the threat of regulation and, by mandating disclosure for all firms, allowed voluntary disclosers to form sharper expectations about future regulatory costs associated with their GHG, based on their industry's GHG performance. Moreover, the interaction between industry-ranking and climate change-relate regulatory concerns having a stronger effect on GHG reductions, lends further support for this channel.

# 7. Conclusion

I study whether, for firms voluntarily disclosing prior to regulation, real effects are larger after disclosure is mandated. Recent studies show that firms providing new, improved, or more disseminated information after mandated reporting improve their CSR outcomes. Whether mandated CSR reporting yields CSR improvements when firms are already being transparent, however, is less understood. My setting is the United Kingdom, which passed a law requiring all UK-incorporated, publicly traded companies to report GHG in financial reports starting in 2013. A key feature of this setting is that a number of firms affected by mandatory carbon reporting (MCR) voluntarily reported GHG prior to the regulation. This allows me to isolate and estimate the magnitude of GHG reductions among voluntarily disclosing firms.

I find that mandated reporting generates real effects among firms that are already disclosing GHG. Specifically, for the full sample and in the most conservative specifications that include firm and year fixed effects, I document that UK firms voluntarily disclosing prior to MCR reduced GHG levels and intensity by around 12% after MCR, relative to non-UK firms that voluntarily disclosed GHG but are unaffected by mandated reporting. A propensity-score matched sample yields similar inferences. To address endogeneity, I use a sample of private UK firms that are not covered by the regulation as the control group and find corroborating results. I also rule-out that GHG reporting changes around MCR, and the shift of GHG data into financial reports for some firms, are driving my results. Regarding the mechanisms, I predict and find that the change in a voluntary discloser's GHG ranking from before to after mandated reporting predicts its GHG reductions and that the effect is stronger for firms that perceive higher climate change-related reputational risks. I also find that the GHG ranking of a voluntary discloser's *industry* predicts the firm's GHG reductions and that this is stronger for firms that perceive higher climate change-related regulatory risks. These cross-sectional findings suggest that mandated reporting provides voluntary disclosers with information about previously non-disclosing firms that allows them to adjust their behaviors in order to (a) remain competitive on the basis of CSR performance (that is, competitive CSR benchmarking) and (b) preempt and/or prepare for future regulation on the basis of new information about industry GHG performance.

My findings contribute to research on the real effects of disclosure regulation by showing that mandated CSR disclosure can elicit behavioral changes among firms that *already voluntarily* disclose. My findings also have policy implications for regulators considering mandated disclosure of environmental and social responsibility data: although thousands of companies around the world voluntarily disclose CSR data, mandated reporting can still improve CSR outcomes, even among the voluntary disclosers.

It is important to note the limitations. First, the main threat to identification is a violation of the parallel trends assumption. Although my evidence supports the validity of the assumption, and I control for events that are likely to affect the results (for example, excluding firms affected by concurrent regulations),

it is possible that other changes cloud my inferences. Second, my focus on a particular UK regulation could limit the generalizability of my findings. Third, although a reduction in GHG likely has benefits, I am unable to speak to all the potential costs and benefits of this regulation and thus cannot draw conclusions about its overall welfare effects. Further, my results speak only to the incremental effects of mandated reporting over voluntary reporting; I cannot compare the effects of more stringent forms of regulation, such as imposing explicit costs on GHG, or of other regulatory mechanisms and tools. A comparison of the effectiveness of various regulatory approaches is undoubtedly an interesting topic for future research.

**References**


Albuquerque, R., Koskinen, Y. and C. Zhang. 2019. Corporate social responsibility and firm risk: Theory and empirical evidence. *Management Science* 65: 4451-4469.

Amel-Zadeh, A. and G. Serafeim. 2018. Why and how investors use ESG information: evidence from a global survey. *Financial Analysts Journal* 74(3): 87-103.

Bertrand, M., Duflo, E. and S. Mullainathan. 2004. How Much Should We Trust Differences-in-Differences Estimates? *Quarterly Journal of Economics* 119(1): 249-75.

Biddle, G.C., Hilary, G. and R.S. Verdi. 2009. How does financial reporting quality relate to investment efficiency? *Journal of Accounting and Economics* 48(2-3): 112–131.

Blacconiere, W.G. and D.M. Patten. 1994. Environmental disclosures, regulatory costs, and changes in firm value. *Journal of Accounting and Economics* 18(3): 357-377.

Bode C, Singh J., and M. Rogan. 2015. Corporate social initiatives and employee retention. *Organization Science* 26(6): 1702–1720.

Burbano, V.C. 2019. Getting Gig Workers to Do More by Doing Good: Field Experimental Evidence. *Organization & Environment*. Early online version: https://journals.sagepub.com/doi/pdf/10.1177/1086026619846455

Castelo Branco, M. and L. Lima Rodrigues. 2006. Corporate social responsibility and resource-based perspectives. *Journal of Business Ethics* 69: 111-132.

Chen, Y., Hung, M. and Y. Wang. 2018. The effect of mandatory CSR disclosure on firm profitability and social externalities: Evidence from China. *Journal of Accounting and Economics* 65(1): 169-190.

Cheng, M., Dhaliwal, D., and Y. Zhang. 2013. Does investment efficiency improve after the disclosure of material weaknesses in internal control over financial reporting? *Journal of Accounting and Economics* 56 (1): 1–18.

Christensen, H., Floyd, E., Liu L. and M. Maffett. 2017. The real effects of mandated information on social responsibility in financial reports: evidence from mine-safety records. *Journal of Accounting and Economics* 64(2-3): 284-304.

Christensen, H., Hail, L. and C. Leuz. 2019. Adoption of CSR and Sustainability Reporting Standards: Economic Analysis and Review. European Corporate Governance Institute - Finance Working Paper No. 623/2019.

Cho, Y. 2015. Segment disclosure transparency and internal capital market efficiency: evidence from SFAS No. 131. *Journal of Accounting Research* 53(4):669–723.

Dahlmann, F., Branicki, L. and S. Brammer. 2017. Managing Carbon Aspirations: The Influence of Climate Change Targets on Environmental Performance. *Journal of Business Ethics* 158(1): 1-24.

Daske, H., Hail, L., Leuz, C. and R. Verdi. 2008. Mandatory IFRS Reporting around the World: Early Evidence on the Economic Consequences. *Journal of Accounting Research* 46(5): 1085-1142.

Dean, S. 2017, July 11. These 100 companies are to blame for 71% of the world's greenhouse gas emissions. Science Alert. Accessed on April 15, 2020 from: https://www.sciencealert.com/these-100-companies-are-to-blame-for-71-of-the-world-s-greenhouse-gas-emissions

Department for Environment, Food & Rural Affairs (DEFRA). November 30, 2010. Press Release: New research shows reporting greenhouse gas emissions benefits business. Accessed on April 2, 2020 from: https://www.gov.uk/government/news/new-research-shows-reporting-greenhouse-gas-emissions-benefits-business

Department for Environment, Food & Rural Affairs (DEFRA). May 2011. Measuring and reporting of greenhouse gas emissions by UK companies: a consultation on options. Accessed on April 2, 2020 from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/82356/110511-ghg-emissions-condoc1.pdf

Department for Environment, Food & Rural Affairs (DEFRA). August 2012. Environmental Reporting Guidelines: Mandatory Greenhouse Gas Emissions Reporting. Accessed on October 1, 2020 from: www.gov.uk/defra.

Ding, R., Levine, R., Lin, C. and W. Xie. 2020. Corporate immunity to the COVID-19 pandemic. NBER Working paper.

Doshi, A., Dowell, G.W. and M.W. Toffel 2013. How firms respond to mandatory information disclosure. *Strategic Management Journal* 34(10): 1209-1231.

Downar, B., J. Ernstberger, S. Reichelstein, S. Schwenen, and A. Zaklan. 2021. The impact of carbon disclosure mandates on emissions and financial operating performance. *Review of Accounting Studies* 26 (3): 1137–1175.

Durand, R., Paugam, L. and H. Stolowy. 2019. Do investors actually value sustainability indices? Replication, development, and new evidence on CSR visibility. *Strategic Management Journal* 40(9): 1471-1490.

Dyreng, S., Hoopes, J. and J. Wilde. 2016. Public pressure and corporate tax behavior. *Journal of Accounting Research* 54(1): 182-215.

Eccles, R., M. Krzus, and G. Serafeim. 2011. Market interest in nonfinancial information. *Journal of Applied Corporate Finance* 23(4): 113-127.

Flammer, C. 2018. Competing for government procurement contracts: The role of corporate social responsibility. *Strategic Management Journal* 39(5): 1299–1324.

Flammer C and J. Luo. 2017. Corporate social responsibility as an employee governance tool: evidence from a quasi-experiment. *Strategic Management Journal* 38(2): 163–183.

Freiberg, D., Grewal, J. and G. Serafeim. 2021. Science-Based Carbon Emissions Targets. Working paper.

Gilbert, M. January 10 2019. The Rising Cost of Investing Responsibly. Bloomberg. Accessed on April 2, 2020 from: https://www.bloomberg.com/opinion/articles/2019-01-11/the-rising-cost-of-esg-andsocially-responsible-investing

Gipper, B. 2016. Assessing the effects on mandated compensation disclosures. Workingpaper.

Graafland, J.J., Eijffinger, S.C.W., and H. SmidJohan. 2004. Benchmarking of Corporate Social Responsibility: Methodological Problems and Robustness. *Journal of Business Ethics* 53(2):137-152.

Graham, J.R., Hanlon, M., T. Shevlin. 2011. Real effects of accounting rules: evidence from multinational firms' investment location and profit repatriation decisions. *Journal of Accounting Research* 49 (1): 137–185.

Granja, J. 2018. Disclosure regulation in commercial banking: lessons from the National Banking Era. *Journal of Accounting Research* 56(1): 173-216.

Grewal, J., Riedl, E. and G. Serafeim. 2019. Market Reaction to Mandatory Nonfinancial Disclosure. *Management Science* 65(7): 2947-3448.

Griffin, P., Lont, D. and E. Sun. 2017. The relevance to investors of greenhouse gas emission disclosures. *Contemporary Accounting Research* 34(2): 1265-97.

Guler, I., Guillén, M.F. and J.M. Macpherson. 2002. Global competition, institutions, and the diffusion of organizational practices: The international spread of ISO 9000 Quality Certificates. *Administrative Science Quarterly* 47(2): 207–232.

Iacus, S.M., King, G. and G. Porro. 2011. Causal inference without balance checking: coarsened exact matching. *Society for Political Methodology*.

Intergovernmental Panel on Climate Change (IPCC). 2018. Global warming of 1.5°C: An IPCC Special Report. Accessed on April 1, 2020 from: https://www.ipcc.ch/sr15/

Ioannou, I., Li, X. and G. Serafeim. 2015. The effect of target difficulty on target completion: The case of reducing carbon emissions. *The Accounting Review* 91(5): 1467-1492.

Jouvenot, V. and P. Krueger. 2021. Mandatory Corporate Carbon Disclosure: Evidence from a Natural Experiment. Working paper.

Kotsantonis, S. and G. Serafeim. 2019. Four things no one will tell you about ESG data. *Journal of Applied Corporate Finance* 31(2): 50-58.

Lins, K.V., Servaes, H. and A. Tamayo. 2017. Social capital, trust, and firm performance: The value of corporate social responsibility during the financial crisis, *Journal of Finance* (72): 1785-1824.

Marquis, C., Toffel, M.W. and Y. Zhou. 2016. Scrutiny, Norms, and Selective Disclosure: A Global Study of Greenwashing. *Organization Science* 27(2): 233-504.

Matsumura, E. M., Rachna Prakash, and S.C. Vera-Muñoz. 2014. Firm-value effects of carbon emissions and carbon disclosures. *The Accounting Review* 89(2): 695-724.

Maxwell, J., Lyon, T. and S. Hackett. 2000. Self-regulation and social welfare: the political economy of corporate environmentalism. *Journal of Law & Economics* 43(2): 583-617.

Nachmany, M., Fankhauser, S., Setzer, J. and A. Averchenkova. 2017. Global trends in climate change legislation and litigation. Accessed on January 28, 2020 from: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2017/04/Global-trends-in-climate-change-legislation-and-litigation-WEB.pdf

Nitoiu, A. 2013. From Voluntary to Mandatory: The evolution of GHG reporting. *Sustainalytics Reporter*, Issue 16.

Pitt, C. 2012. How to stay on top of the CRC league table. Business Green. Accessed on April 15, 2020 from: https://www.businessgreen.com/sponsored/2124733/stay-crc-league-table

Rauter, T. 2020. The effect of mandatory extraction payment disclosures on corporate payment and investment policies abroad. *Journal of Accounting Research* 58(5): 1075-1116.

Roberts, P.W. and G.R. Dowling. 2002. Corporate reputation and sustained superior financial performance. *Strategic Management Journal* 23(12): 1077-1093.

Rosenbaum, P. R., and D. B. Rubin. 1985. Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. *The American Statistician* 39(1): 33-38.

Rupp D.E., Shao R., Thornton M.A. and D.P. Skarlicki. 2013. Applicants' and employees' reactions to corporate social responsibility: the moderating effects of first-party justice perceptions and moral identity. *Personnel Psychology* 66(4): 895–933.

Shen, L. 2017, July 10. These 100 companies are responsible for most of the world's carbon emissions. Fortune. Accessed on March 28, 2020 from: https://fortune.com/2017/07/10/climate-change-green-house-gases/

Shroff, N., 2017. Corporate investment and changes in GAAP. *Review of Accounting Studies* 22(1): 1–63.

Simnett, R., Nugent, M. and A.L. Huggins. 2009. Developing an international assurance standard on greenhouse gas statements. *Accounting Horizons* 23(4): 347-363.

SRI-Connect (SRI). 2020. Independent Research in Responsible Investment Survey. Accessed on October 20, 2020 from: http://www.sri-connect.com/index.php?option=com_content&view=category&layout=blog&id=211&Itemid=1987

Taebi, B. and A. Safari. 2017. On effectiveness and legitimacy of 'shaming' as a strategy for combatting climate change. *Science and Engineering Ethics* 23(5): 1289-1306.

Taylor, M. and J. Watts. 2019, October 9. Revealed: the 20 firms behind a third of all carbon emissions. The Guardian. Accessed on April 15, 2020 from: https://www.theguardian.com/environment/2019/oct/09/revealed-20-firms-third-carbon-emissions

Tingley, D. and M. Tomz. 2020. The effects of naming and shaming on public support for compliance with international agreements: An experimental analysis of the Paris Agreement. Workingpaper.

Tomar, S. 2023. Greenhouse gas disclosure and emissions benchmarking. *Journal of Accounting Research*, 61 (2): 451-492.

Watts, J. 2020. Naming and shaming the polluters. Podcast from the Guardian, accessed on April 2, 2020 from: https://www.theguardian.com/environment/audio/2019/oct/18/naming-and-shaming-the-polluters

Zellner, A. 1962. An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias. *Journal of the American Statistical Association* 57(298): 348-368.

**Appendix A: Variable Definitions**

| | |
|---|---|
| $GHG\_Level_{it}$ | Natural logarithm of total Scope 1 and Scope 2 greenhouse gas emissions in metric tons of carbon dioxide equivalent for firm *i* in year *t*. |
| $GHG\_Intensity_{it}$ | Natural logarithm of total Scope 1 and Scope 2 greenhouse gas emissions in metric tons of carbon dioxide equivalent emitted per unit of revenue for firm *i* in year *t*. |
| *CarbonReductionCommitment* | Indicator equal to 1 for firms covered by the Carbon Reduction Commitment (CRC) Energy Efficiency Scheme, 0 otherwise. |
| $Assets_{it}$ | Natural logarithm of total assets for firm *i* in year *t*, from Bloomberg. |
| $Revenue_{it}$ | Natural logarithm of total revenues for firm *i* in year *t*, from Bloomberg. |
| $ROA_{it}$ | Ratio of income before extraordinary items over total assets for firm *i* in year *t*, expressed as a percentage, from Bloomberg. |
| $PTB_{it}$ | Market to book value for firm *i* in year *t*, expressed as a percentage, from Bloomberg. |
| $Leverage_{it}$ | Ratio of total liabilities to total assets for firm *i* in year *t*, expressed as a percentage, from Bloomberg. |
| $Capex_{it}$ | Ratio of capital expenditures to sales revenues for firm *i* in year *t*, expressed as a percentage, from Bloomberg. |
| $SalesGrowth_{it}$ | Sales revenues for firm *i* in year *t* divided by sales revenues for firm *i* in year *t-4*, reduced to a compound annual rate, from Bloomberg. |
| $GridCarbonIntensity_{ct}$ | Average amount of carbon dioxide emitted to produce electricity for country *c* in year *t*. Measured in grams of carbon dioxide equivalent per kilowatt hour of electricity (gC02e/kWh) and averaged over year *t* across regions in country *c*. Obtained from the International Energy Agency's publication *Emissions factors* (2019 edition). |
| $GDP_{ct}$ | Gross Domestic Product for country *c* in year *t*, in trillions. Obtained from World Development Indicators. |
| $Treat_i$ | Indicator equal to 1 for firms affected by Mandatory Carbon Reporting, 0 otherwise. |
| $Control_i$ | Indicator equal to 1 for firms unaffected by Mandatory Carbon Reporting, 0 otherwise. |
| $Post_t$ | Indicator equal to 1 in years after Mandatory Carbon Reporting comes into effect, 0 otherwise. |
| $Likelihood_i$ | Firm *i*'s assessment of the likelihood that climate change-related reputational or regulatory risks will impact business, from CDP response data in 2012. Responses are measured between 1 and 8 as follows: 1 = Exceptionally unlikely; 2 = Very unlikely; 3 = Unlikely; 4 = About as likely as not; 5 = More likely than not; 6 = Likely; 7 = Very likely; 8 = Virtually certain. |

| | |
|---|---|
| $Magnitude_i$ | Firm *i*'s assessment of the magnitude of impact that climate change-related reputational or regulatory risks will have on business, from CDP response data in 2012. Responses are measured between 1 and 5 as follows: 1 = Low; 2 = Low-medium; 3 = Medium; 4 = Medium-high; 5 = High. |
| $Timeframe_i$ | Firm *i*'s assessment of the timeframe that climate change-related reputational or regulatory risks will impact business, from CDP response data in 2012. Responses are measured between 1 and 6 as follows: 1 = Over 10 years; 2 = 6 to 10 years; 3 = 3 to 6 years; 4 = 1 to 3 years; 5 = Up to 1 year; 6 = Current. |
| $ReputationRisk_i$ | Product of likelihood, magnitude and timeframe (*Likelihood* x *Magnitude* x *Timeframe*) for climate change reputation risks. |
| $RegulationRisk_i$ | Product of likelihood, magnitude and timeframe (*Likelihood* x *Magnitude* x *Timeframe*) for climate change regulation risks. |
| *ΔGHG_Ranking* | Difference between the firm's ranking in 2013 (the first year MCR is in effect) less the firm's ranking in 2012, where the highest-emitting firm is assigned a value of 1 and the lowest emitter is assigned a value of 0. Unlogged values of *GHG_Level* are normalized within each industry. If the difference is positive, this indicates that a voluntary discloser had a worse ranking once the GHG data of first-time disclosers is revealed, while a negative difference indicates an improved ranking. |
| *Industry_GHG_Ranking* | Industry ranking of GHG levels in 2013 (first year that MCR is in effect) measured as the average, unlogged *GHG_Level* in 2013 across all firms in the industry and normalized so that all of the firms operating in the industry with the highest average unlogged *GHG_Level* in 2013 are assigned a value of 1, and all firms operating in the industry with the lowest average unlogged *GHG_Level* in 2013 are assigned a value of 0. |

**Appendix B: Summary of Confounding Regulations**

| | Confound | Affected Firms | Description | Strategy to control for confound |
|---|---|---|---|---|
| 1 | Financial incentive to reduce emissions | UK and EU firms | Carbon Reduction Commitment (CRC) Energy Efficiency Scheme began in 2009 and is a mandatory scheme to improve energy efficiency among certain large organizations that are not part of the EU Emissions Trading Scheme (EU ETS). Covered (large, energy-intensive) organizations must report emissions and buy allowances for covered emissions. The price increased from £12.00/tCO2 to £16.40/tCO2 in 2014. | Subtract covered emissions from total emissions for firms that are covered by the CRC, identified using data from the UK Environment Agency. |
| 2 | Financial incentive to reduce emissions | UK firms | Carbon Price Floor (CPF) was introduced in April 2013. CPF is a top-up tax imposed on energy producers in the UK, paid to the UK treasury. It exists to address low carbon prices in the European Union Emissions Trading Scheme (EU ETS). | Remove UK energy producers from the remaining sample, identified using Utilities GICS codes 551010-551050. |
| 3 | Financial incentive to reduce emissions | EU firms | European Union Emissions Trading Scheme (EU ETS) began in 2005 and is the largest mandatory trading and reporting scheme in the world. Affects power generation and manufacturing operators in the EU. Several changes occurred in the sample period that differentially affect UK firms and other European firms. | Remove firms from the remaining sample that are covered by the EU ETS, identified using the Ownership Links and Enhanced EUTL Dataset. |
| 4 | Financial incentive to reduce emissions | UK firms | Climate Change Levy (CCL) is an energy consumption tax on UK companies that began in 2001. Companies get a discount if they voluntarily commit to and meet government energy targets. In 2013, the discount increased from 65% to 90% of the CCL rate. | Perform within-UK analysis because CCL rules and changes apply to public and private UK firms. |
| 5 | Financial incentive to reduce emissions | Non-UK firms | Carbon taxes and emissions cap-and-trade schemes came into effect in other countries during the sample period. | Remove firms from: Australia, Bulgaria, Chile, Colombia, Ireland, Japan, New Zealand, Singapore and Switzerland. |
| 6 | Mandatory Carbon Reporting | Non-UK firms | Regulations to mandate emissions reporting came into effect in other countries during the sample period. | Remove firms from: South Africa, South Korea and USA. |

**Appendix C: Comparability of GHG reporting before and after MCR**

The purpose of this table is to determine whether GHG reporting is comparable between the pre- and post-periods for treatment (UK firms) and control (non-UK) firms. MCR's requirements come from the guidelines issued by the UK government in 2012 after MCR was announced; see Environmental Reporting Guidelines: Mandatory Greenhouse Gas Emissions Reporting from www.gov.uk/defra. I collect data on the reporting elements from the same sources where I collect GHG information; see Section 4.2. The CDP survey question that I use is specified, if applicable; I note that these questions are worded consistently throughout the sample period.

| **Reporting Element** | **Requirement under MCR** | **CDP survey question utilized, if applicable** | **# firms that change around MCR** |
|---|---|---|---|
| Methodology | Firms are required to use a widely recognized and independent methodology such as the International Organisation for Standardization Standard 14064-1 or the GHG Protocol. | *"Please give the name of the standard, protocol or methodology you have used to collect activity data and calculate Scope 1 and Scope 2 emissions"* | 11 UK firms (26 non-UK firms) changed methodology. |
| Boundary | Firms are required to calculate GHG from activities over which they have financial or operational control. | *"Please state the boundary you are using for your Scope 1 and 2 emissions"* | 8 UK firms (17 non-UK firms) changed reporting boundary. |
| Period | Firms must calculate GHG over the 12-month period corresponding to their fiscal year. | *"Please state the start and end date of the year for which you are reporting Scope 1 and Scope 2 emissions"* | 13 UK firms (33 non-UK firms) changed reporting period. |
| Scope | Scope refers to the source of emissions, and firms are required to calculate GHG from Scope 1 and 2 sources. | N/A - Scope is implicit given that the above questions pertain to Scope 1 and 2 emissions. | 18 UK firms (37 non-UK firms) changed reporting scope. |
| Intensity Ratio | Firms must report a ratio that divides total annual GHG by an activity measure . | *"Please state your intensity figure as gross combined Scope 1 and 2 emissions for the reporting year in metric tons of carbon dioxide equivalent per unit total revenue."* | None. As noted in Section 4.3, the CDP survey asks firms to report an intensity ratio that normalizes GHG by revenues. |
| Disclosure Channel | Firms must disclose GHG data within annual Directors' Report (the UK equivalent of SEC Form 10-K) | N/A - see Section 4.2 information on how I identify where firms disclose GHG data | 86 UK firms and 11 non-UK firms shift GHG data into financial reports in the post-period. |
| Assurance | Assurance over GHG data is recommended, but not required. | *"Please indicate the assurance status that applies to your reported emissions"* and "*Attach the assurance statement if applicable"*. | I do not observe firms switching between assurance and non-assurance of GHG around MCR. |

**Figure 1: Treatment and Control Samples**

| Voluntary Discloser | Mandatory Discloser |
|---|---|
| Pre | Post |

**Treatment firms:** UK firms that voluntarily disclose GHG prior to mandated reporting

| Voluntary Discloser | Voluntary Discloser |
|---|---|
| Pre | Post |

**Control firms:** non-UK firms that voluntarily disclose GHG but are unaffected by mandated reporting

**My Research Design**

| Non-Discloser | Mandatory Discloser |
|---|---|
| Pre | Post |

**Research design in prior studies**

**Figure 2: Greenhouse Gas Emissions in Event Time**
This figure reports coefficients and 95% confidence intervals of OLS regressions estimating the effect of Mandatory Carbon Reporting on *GHG_Level* (defined in Appendix A). I estimate model (1) but replace *Treat x Post* with separate interaction terms, each representing one time period relative to the year the mandate comes into effect (t=0).

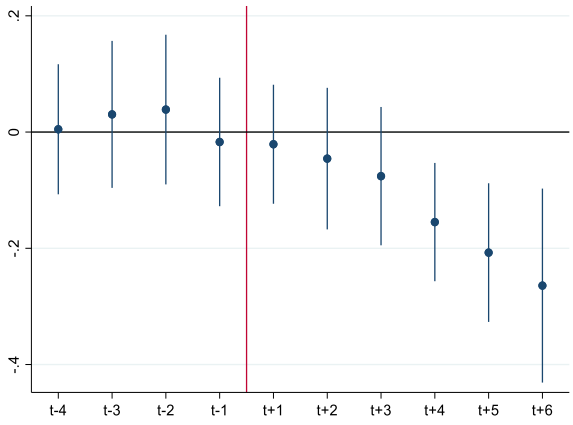


**Figure 3: Greenhouse Gas Emissions Intensity in Event Time**
This figure reports coefficients and 95% confidence intervals of OLS regressions estimating the effect of Mandatory Carbon Reporting on *GHG_Intensity* (defined in Appendix A). I estimate model (1) but replace *Treat x Post* with separate interaction terms, each representing one time period relative to the year the mandate comes into effect (t=0).

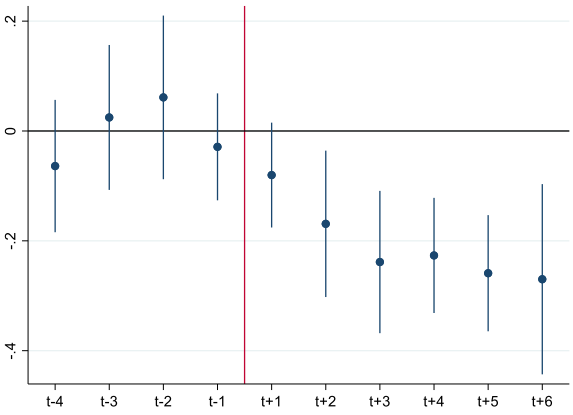


**Figure 4: Greenhouse Gas Emissions in Event Time (Matched Sample)**
This figure reports coefficients and 95% confidence intervals of OLS regressions estimating the effect of Mandatory Carbon Reporting on *GHG_Level* (defined in Appendix A) for the matched sample. I estimate model (1) but replace *Treat x Post* with separate interaction terms, each representing one time period relative to the year the mandate comes into effect (t=0).

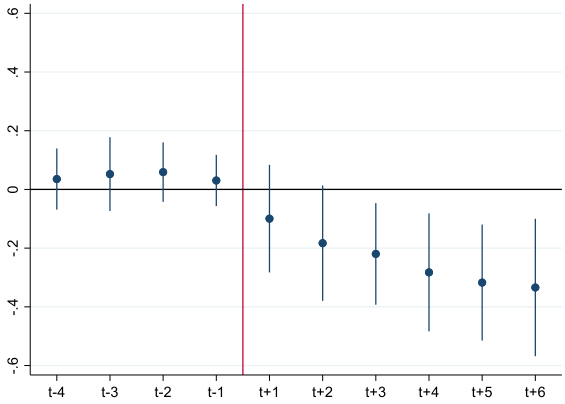

**Figure 5: Greenhouse Gas Emissions Intensity in Event Time (Matched Sample)**
This figure reports coefficients and 95% confidence intervals of OLS regressions estimating the effect of Mandatory Carbon Reporting on *GHG_Intensity* (defined in Appendix A) for the matched sample. I estimate model (1) but replace *Treat x Post* with separate interaction terms, each representing one time period relative to the year the mandate comes into effect (t=0).

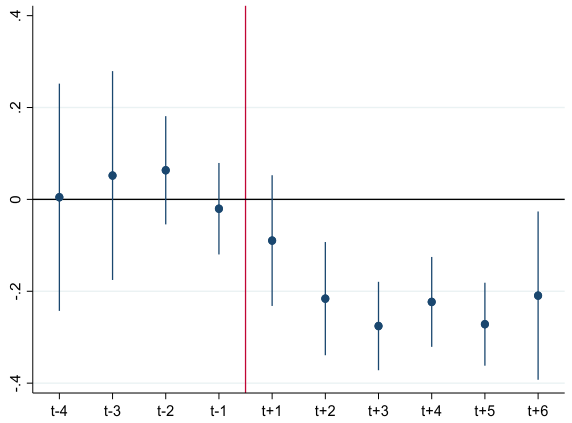


**Figure 6: Greenhouse Gas Emissions in Event Time (Private and Public UK firms)**
This figure reports coefficients and 95% confidence intervals of OLS regressions estimating the effect of Mandatory Carbon Reporting on *GHG_Level* (defined in Appendix A) for treated UK firms and control non-UK firms that disclose GHG outside of financial reports before MCR. I estimate model for the matched sample (1) but replace *Treat x Post* with separate interaction terms, each representing one time period relative to the year the mandate comes into effect (t=0).

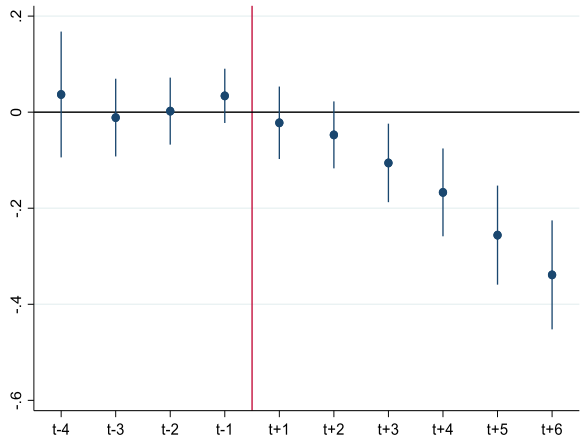


**Figure 7: Greenhouse Gas Emissions Intensity in Event Time (Private and Public UK firms)**
This figure reports coefficients and 95% confidence intervals of OLS regressions estimating the effect of Mandatory Carbon Reporting on *GHG_ Intensity* (defined in Appendix A) for public and private UK firms. I estimate model (1) for the UK sample, but replace *Treat x Post* with separate interaction terms, each representing one time period relative to the year the mandate comes into effect (t=0).

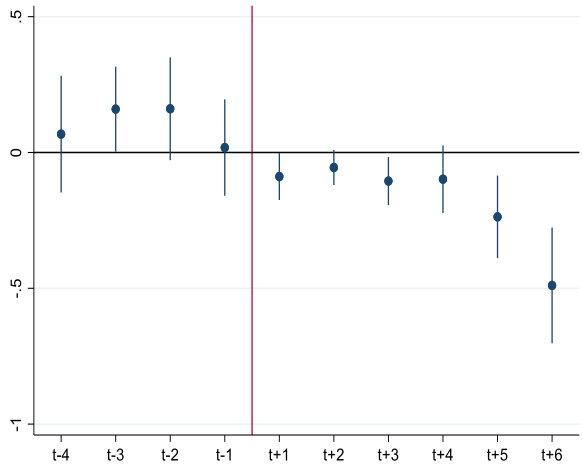

**Table 1. Sample Construction**

| | |
|---|---|
| Firms listed on the London Stock Exchange as of June 30, 2012 | 2,530 |
| Remove: Alternative Investment Market shares not subject to MCR | -1,171 |
| Remove: depository receipts, fixed interest securities, warrants | -339 |
| Remove: firms not incorporated in UK | -106 |
| Remove: equity investment instruments | -349 |
| **Listed UK firms covered by MCR** | **565** |
| Remove: firms with confounding carbon regulations (see Appendix B) | -37 |
| **Remaining UK firms covered by MCR** | **528** |
| Less: missing or insufficient GHG data prior to MCR | -332 |
| Less: inconsistent GHG reporting around MCR | -46 |
| **UK sample** | **150** |
| **Listed non-UK sample eligible for matching** | **281** |
| **Total # of listed UK and non-UK firms** | **431** |
| **Firm-years** | **4,387** |

**Table 2. Summary Statistics**

| Variable name | N | Mean | Median | SD |
|---|---|---|---|---|
| GHG Level (metric tons of CO2 e) | 4,387 | 4,070,186 | 218,586 | 15,500,000 |
| GHG Intensity (GHG/revenues) | 4,387 | 0.00038 | 0.00004 | 0.00146 |
| *Assets* | 4,387 | 23.15 | 22.93 | 1.93 |
| *ROA* | 4,387 | 7.49 | 6.07 | 6.35 |
| *PTB* | 4,387 | 3.09 | 2.04 | 4.26 |
| *Leverage* | 4,387 | 109.77 | 60.23 | 166.43 |
| *Capex* | 4,387 | 8.97 | 4.26 | 14.10 |
| *SalesGrowth* | 4,387 | 6.40 | 4.97 | 21.57 |
| *GridCarbonIntensity* | 4,387 | 532.41 | 372.00 | 939.74 |
| *GDP* | 4,387 | 2.12 | 2.47 | 1.23 |

Notes: *Assets* is natural log-transformed.

**Table 3. Pearson Correlations**

| Variables | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1. *GHG_Level* | | | | | | | | | |
| 2. *GHG_Intensity* | **0.36** | | | | | | | | |
| 3. *Assets* | **0.39** | **-0.04** | | | | | | | |
| 4. *ROA* | **-0.06** | **-0.10** | **-0.47** | | | | | | |
| 5. *PTB* | **-0.10** | **-0.07** | **-0.18** | **0.25** | | | | | |
| 6. *Leverage* | 0.02 | **-0.04** | **0.39** | **-0.22** | **0.12** | | | | |
| 7. *Capex* | **0.25** | **0.19** | 0.02 | **-0.28** | **-0.10** | 0.00 | | | |
| 8. *SalesGrowth* | -0.02 | **-0.06** | 0.01 | 0.03 | **0.05** | -0.02 | **-0.04** | | |
| 9. *GridCarbonIntensity* | **0.12** | **0.11** | **-0.06** | 0.00 | **0.05** | **-0.03** | **0.12** | **0.09** | |
| 10. *GDP* | **-0.11** | **-0.03** | **-0.14** | **0.07** | **0.07** | -0.01 | **-0.03** | **0.04** | **0.68** |

**Boldface** indicates significance at the 5% level or better

**Table 4. Country Representation**

| | Treatment | | Control | |
|---|---|---|---|---|
| | # | % | # | % |
| United Kingdom | 150 | 100% | 0 | 0% |
| Belgium | | | 10 | 4% |
| Canada | | | 56 | 20% |
| China | | | 5 | 2% |
| Denmark | | | 4 | 1% |
| Finland | | | 5 | 2% |
| France | | | 56 | 20% |
| Germany | | | 13 | 5% |
| Greece | | | 4 | 1% |
| Hong Kong | | | 14 | 5% |
| Hungary | | | 2 | 1% |
| India | | | 27 | 10% |
| Italy | | | 2 | 1% |
| Luxembourg | | | 5 | 2% |
| Netherlands | | | 23 | 8% |
| Norway | | | 1 | 0% |
| Poland | | | 5 | 2% |
| Portugal | | | 6 | 2% |
| Russia | | | 2 | 1% |
| Spain | | | 21 | 7% |
| Sweden | | | 14 | 5% |
| Turkey | | | 6 | 2% |
| | 150 | 100% | 281 | 100% |

**Table 5. Full Sample Estimates of the Effect of Mandatory Carbon Reporting on GHG**
**Panel A: Greenhouse gas emissions in levels**

| | Sample: Listed UK and Non-UK Firms<br>Dependent Variable: *GHG_Level* | | |
|---|---|---|---|
| Variables | (1) | (2) | (3) |
| Treat x Post | -0.374***<br>(-3.65) | -0.123**<br>(-2.27) | -0.126***<br>(-2.84) |
| *Post* | 0.0662<br>(1.05) | | |
| *Treat* | -2.028***<br>(-4.18) | | |
| *Assets* | | | 0.624***<br>(6.21) |
| *ROA* | | | 0.0287**<br>(2.48) |
| *PTB* | | | -0.00488<br>(-1.26) |
| *Leverage* | | | 1.10e-05<br>(0.10) |
| *Capex* | | | -0.00491<br>(-1.67) |
| *SalesGrowth* | | | -0.000681<br>(-1.33) |
| *GridCarbonIntensity* | | | 3.44e-05<br>(0.17) |
| *GDP* | | | 0.110***<br>(2.85) |
| *CarbonReductionCommitment* | 0.767*<br>(1.86) | | |
| constant | 13.14***<br>(28.41) | 12.50***<br>(159.20) | -2.119<br>(-0.94) |
| Firm fixed effects | No | Yes | Yes |
| Year fixed effects | No | Yes | Yes |
| Observations (firm-years) | 4,387 | 4,387 | 4,387 |
| Adj. $R^2$ | 0.152 | 0.967 | 0.973 |

**Panel B: Greenhouse gas emissions scaled by revenue**

| | Sample: Listed UK and Non-UK Firms<br>Dependent Variable: *GHG_Intensity* | | |
|---|---|---|---|
| Variables | (1) | (2) | (3) |
| Treat x Post | -0.311***<br>(-3.62) | -0.149***<br>(-3.52) | -0.124***<br>(-3.20) |
| *Post* | 0.0631<br>(1.04) | | |
| *Treat* | -0.689*<br>(-1.91) | | |
| *Assets* | | | -0.213***<br>(-3.30) |
| *ROA* | | | -0.0516***<br>(-6.43) |
| *PTB* | | | -0.00823*<br>(-1.98) |
| *Leverage* | | | 6.42e-05<br>(0.51) |
| *Capex* | | | 0.000652<br>(0.13) |
| *SalesGrowth* | | | -0.00271***<br>(-6.58) |
| *GridCarbonIntensity* | | | 1.61e-05<br>(0.07) |
| *GDP* | | | 0.0738*<br>(1.87) |
| *CarbonReductionCommitment* | -0.0808<br>(-0.22) | | |
| constant | -9.575***<br>(-19.50) | -9.638***<br>(-68.57) | -4.509***<br>(-3.20) |
| Firm fixed effects | No | Yes | Yes |
| Year fixed effects | No | Yes | Yes |
| Observations (firm-years) | 4,387 | 4,387 | 4,387 |
| Adj. $R^2$ | 0.035 | 0.954 | 0.958 |

Notes: Robust standard errors clustered by industry and *t*-statistics reported in parentheses; ***p<0.01, **p<0.05, *p<0.10. All variables are defined in Appendix A.

**Table 6. Matched Sample Estimates of the Effect of Mandatory Carbon Reporting on GHG**
**Panel A: Covariate Balance in Full and Matched Samples**

| Sample | Full Sample Before Matching | | | Sample After Matching | | |
|---|---|---|---|---|---|---|
| | Treatment | Control | t-stat | Treatment | Control | t-stat |
| GHG Level (metric tons of CO2 e) | 1,466,159 | 5,385,945 | **2.58** | 2,049,011 | 1,707,148 | 0.33 |
| *Assets* | 22.19 | 23.61 | **7.25** | 22.50 | 23.19 | 1.51 |
| *ROA* | 9.29 | 6.73 | **3.59** | 9.49 | 6.85 | **2.36** |
| *PTB* | 3.78 | 2.37 | **3.35** | 3.55 | 3.07 | -0.73 |
| *Leverage* | 107.57 | 127.66 | 0.95 | 110.90 | 137.18 | 0.82 |
| *Capex* | 6.25 | 12.14 | **3.86** | 6.88 | 9.97 | 1.70 |
| *SalesGrowth* | 5.48 | 6.08 | 0.30 | 4.59 | 3.45 | -0.41 |
| # of firms | 150 | 281 | | 79 | 79 | |

Notes: Unit of analysis is a firm. *t*-statistics corresponding to p<5% are represented in boldface. Matching is done in 2012, the year before the regulation came into effect.

**Panel B: Greenhouse gas emissions in levels**

| | Sample: Matched Listed UK and Non-UK Firms | | |
|---|---|---|---|
| | Dependent Variable: *GHG_Level* | | |
| Variables | (1) | (2) | (3) |
| Treat x Post | -0.419** | -0.199** | -0.125* |
| | (-2.78) | (-2.80) | (-1.75) |
| *Post* | 0.0285 | | |
| | (0.28) | | |
| *Treat* | -0.976** | | |
| | (-2.12) | | |
| *Assets* | | | 0.543*** |
| | | | (3.37) |
| *ROA* | | | 0.0123 |
| | | | (0.98) |
| *PTB* | | | -0.00685 |
| | | | (-1.12) |
| *Leverage* | | | 5.61e-05 |
| | | | (0.34) |
| *Capex* | | | -0.00996*** |
| | | | (-6.01) |
| *SalesGrowth* | | | -0.00108** |
| | | | (-2.37) |
| *GridCarbonIntensity* | | | 0.000291 |
| | | | (0.71) |
| *GDP* | | | 0.0614 |
| | | | (0.88) |
| *CarbonReductionCommitment* | 0.657 | | |
| | (1.29) | | |
| constant | 12.51*** | 12.32*** | -0.285 |
| | (28.71) | (108.70) | (-0.08) |
| Firm fixed effects | No | Yes | Yes |
| Year fixed effects | No | Yes | Yes |
| Observations (firm-years) | 1,994 | 1,994 | 1,994 |
| Adj. $R^2$ | 0.051 | 0.963 | 0.971 |

**Panel C: Greenhouse gas emissions scaled by revenue**

| | Sample: Matched Listed UK and Non-UK Firms | | |
|---|---|---|---|
| | Dependent Variable: *GHG_Intensity* | | |
| Variables | (1) | (2) | (3) |
| Treat x Post | -0.312** | -0.172** | -0.167** |
| | (-1.97) | (-2.08) | (-1.96) |
| *Post* | 0.0357 | | |
| | (0.28) | | |
| *Treat* | -0.286 | | |
| | (-0.91) | | |
| *Assets* | | | -0.262** |
| | | | (-2.31) |
| *ROA* | | | -0.0619*** |
| | | | (-7.31) |
| *PTB* | | | -0.00916 |
| | | | (-1.31) |
| *Leverage* | | | 0.000109 |
| | | | (0.73) |
| *Capex* | | | -0.00664*** |
| | | | (-3.69) |
| *SalesGrowth* | | | -0.00337*** |
| | | | (-8.68) |
| *GridCarbonIntensity* | | | 0.000113 |
| | | | (0.28) |
| *GDP* | | | 0.0872 |
| | | | (1.08) |
| *CarbonReductionCommitment* | -0.172 | | |
| | (-0.43) | | |
| constant | -9.763*** | -9.686*** | -3.472 |
| | (-19.51) | (-48.96) | (-1.33) |
| Firm fixed effects | No | Yes | Yes |
| Year fixed effects | No | Yes | Yes |
| Observations (firm-years) | 1,994 | 1,994 | 1,994 |
| Adj. $R^2$ | 0.022 | 0.953 | 0.959 |

Notes: Robust standard errors clustered by industry and *t*-statistics reported in parentheses; ***p<0.01, **p<0.05, *p<0.10. All variables are defined in Appendix A.

**Table 7. Within-UK Estimates of the Effect of Mandatory Carbon Reporting on GHG**

**Panel A. Covariate Balance in Within-UK Sample**

| | Treatment | Control | t-stat |
|---|---|---|---|
| GHG Level (metric tons of C02 e) | 1,487,404 | 1,686,984 | 0.13 |
| *Assets* | 21.73 | 21.53 | -0.45 |
| *ROA* | 9.06 | 7.96 | -0.65 |
| *Leverage* | 130.42 | 108.08 | -0.41 |
| # of firms | 150 | 45 | |

Notes: Unit of analysis is a firm. *t*-statistics corresponding to p<5% are represented in boldface. Variables are measured in 2012, the year before the regulation came into effect.

**Panel B: Greenhouse gas emissions in levels**

| | Sample: Listed UK and Private UK Firms | | |
|---|---|---|---|
| | Dependent Variable: *GHG_Level* | | |
| Variables | (1) | (2) | (3) |
| Treat x Post | -0.540*** | -0.297*** | -0.229** |
| | (-4.07) | (-2.71) | (-2.38) |
| *Post* | 0.104 | | |
| | (0.95) | | |
| *Treat* | 0.372 | | |
| | (0.92) | | |
| *Assets* | | | 0.587*** |
| | | | (5.97) |
| *ROA* | | | 0.0278 |
| | | | (1.65) |
| *Leverage* | | | 1.82e-05 |
| | | | (0.20) |
| *CarbonReductionCommitment* | 1.000*** | | |
| | (3.06) | | |
| constant | 10.47*** | 11.11*** | -1.871 |
| | (28.66) | (107.80) | (-0.84) |
| Firm fixed effects | No | Yes | Yes |
| Year fixed effects | No | Yes | Yes |
| Observations (firm-years) | 2,390 | 2,390 | 2,390 |
| Adj. $R^2$ | 0.056 | 0.961 | 0.967 |

**Panel C: Greenhouse gas emissions scaled by revenue**

| | Sample: Listed UK and Private UK Firms<br>Dependent Variable: *GHG_Intensity* | | |
|---|---|---|---|
| Variables | (1) | (2) | (3) |
| Treat x Post | -0.225**<br>(-2.09) | -0.157<br>(-1.60) | -0.188**<br>(-2.06) |
| *Post* | -0.132<br>(-1.47) | | |
| *Treat* | -0.453<br>(-1.53) | | |
| *Assets* | | | -0.238***<br>(-2.82) |
| *ROA* | | | -0.0580***<br>(-6.46) |
| *Leverage* | | | 4.81e-05<br>(0.59) |
| *CarbonReductionCommitment* | 0.244<br>(1.06) | | |
| constant | -10.05***<br>(-35.71) | -9.990***<br>(-119.00) | -4.344**<br>(-2.30) |
| Firm fixed effects | No | Yes | Yes |
| Year fixed effects | No | Yes | Yes |
| Observations (firm-years) | 2,390 | 2,390 | 2,390 |
| Adj. $R^2$ | 0.032 | 0.933 | 0.937 |

Notes: Robust standard errors clustered by firm and *t*-statistics reported in parentheses; ***p<0.01, **p<0.05, *p<0.10. All variables are defined in Appendix A.

**Table 8. Subsample Tests of the Effect of Mandatory Carbon Reporting on GHG**

| Sample: Listed UK & Non-UK firms | Financial-report disclosers | Non-financial-report disclosers | GHG Assurance | No GHG Assurance |
|---|---|---|---|---|
| | *GHG_Level* | *GHG_Level* | *GHG_Level* | *GHG_Level* |
| Variables | (1) | (2) | (3) | (4) |
| Treat x Post | -0.293* | -0.235* | -0.260** | -0.385*** |
| | (-1.83) | (-1.73) | (-2.34) | (-3.09) |
| Post | 0.0141 | 0.0575 | -0.0127 | 0.121 |
| | (0.12) | (0.46) | (-0.10) | (1.31) |
| Treat | -1.593** | -0.198 | -0.464 | -1.334** |
| | (-2.71) | (-0.52) | (-1.63) | (-2.64) |
| *Assets* | 0.575*** | 0.628*** | 0.638*** | 0.497** |
| | (3.51) | (4.08) | (4.44) | (2.69) |
| *ROA* | 0.0794** | 0.119** | 0.118** | 0.0816** |
| | (2.15) | (2.50) | (2.23) | (2.46) |
| *PTB* | -0.0574* | 0.0213 | 0.0302 | -0.0209 |
| | (-1.94) | (0.99) | (0.86) | (-0.87) |
| *Leverage* | -0.00117 | -0.00217* | -0.00276** | 0.000261 |
| | (-0.96) | (-1.78) | (-2.59) | (0.23) |
| *Capex* | 0.0602*** | 0.0440*** | 0.0523*** | 0.0365** |
| | (3.33) | (4.06) | (4.15) | (2.71) |
| *SalesGrowth* | -0.00277 | -0.00380*** | -0.00624*** | 0.000619 |
| | (-1.09) | (-2.82) | (-3.30) | (0.36) |
| *GDP* | -0.0460 | -0.328 | -0.0626 | -0.117 |
| | (-0.19) | (-1.20) | (-0.42) | (-0.38) |
| *GridCarbonIntensity* | 0.000526* | 0.000473 | 0.00022 | 0.000374 |
| | (1.75) | (1.33) | (1.05) | (1.14) |
| *CarbonReductionCommitment* | 0.368 | 0.0142 | 0.0422 | 0.744 |
| | (1.04) | (0.02) | (0.05) | (0.23) |
| constant | -1.058 | -2.623 | -2.869 | 0.457 |
| | (-0.29) | (-0.77) | (-0.91) | (0.11) |
| | Comparison of coefficients Treat x Post: Test for (1) > (2) Null hypothesis (1) = (2) P-value 0.78 | | Comparison of coefficients Treat x Post: Test for (3) > (4) Null hypothesis (3) = (4) P-value 0.42 | |
| Observations (firm-years) | 1,631 | 2,756 | 2,604 | 1,783 |
| Adj. $R^2$ | 0.461 | 0.286 | 0.276 | 0.426 |

Notes: Robust standard errors clustered by industry and *t*-statistics reported in parentheses; ***p<0.01, **p<0.05, *p<0.10. Below the specifications, I report the statistical significance of the differences in coefficient estimates for Treat x Post, based on a system of seemingly unrelated regressions that jointly estimates the models and takes into account correlations in residuals across the regressions (Zellner 1962). This procedure uses a common sample for the two regressions and allows to explicitly test whether the coefficients on the independent variables are different across the two models.

**Table 9: Competitive CSR Benchmarking and Regulatory Costs**

| Dependent Variable: | ln(ΔGHG_Level) | ln(ΔGHG_Level) | ln(ΔGHG_Level) | ln(ΔGHG_Level) |
|---|---|---|---|---|
| Variables | (1) | (2) | (3) | (4) |
| *ΔGHG_Ranking* | -0.0855** | 0.0625 | | |
| | (-2.54) | (0.69) | | |
| *ΔGHG_Ranking* x *ReputationRisk* | | -0.0439** | | |
| | | (-2.26) | | |
| *Industry_GHG_Ranking* | | | -0.0536*** | -0.00588*** |
| | | | (-4.03) | (-5.29) |
| *Industry_GHG_Ranking x RegulationRisk* | | | | -0.0534*** |
| | | | | (-4.37) |
| *ReputationRisk* | | 1.37e-05 | | |
| | | (1.28) | | |
| *RegulationRisk* | | | | 9.26e-06* |
| | | | | (1.83) |
| *Δ Assets* | 0.000499 | 0.000578 | 0.000103 | 0.000158 |
| | (0.96) | (1.04) | (0.93) | (1.43) |
| *Δ ROA* | 0.000169 | 0.000173 | 4.88e-05 | 6.38e-05 |
| | (1.68) | (1.32) | (1.53) | (1.33) |
| *Δ PTB* | 4.77e-05 | 2.85e-05 | 1.97e-06 | -2.09e-05 |
| | (1.33) | (0.88) | (0.09) | (-0.83) |
| *Δ Leverage* | 3.27e-07 | -7.03e-07 | 3.63e-08 | 1.27e-08 |
| | (0.26) | (-0.48) | (0.06) | (0.02) |
| *Δ Capex* | -2.29e-05 | -2.85e-05 | 1.90e-05 | 2.39e-05 |
| | (-0.47) | (-0.61) | (0.94) | (1.01) |
| *Δ SalesGrowth* | 5.28e-06 | 1.38e-05 | -1.67e-05 | -1.78e-05 |
| | (0.52) | (1.09) | (-1.63) | (-1.55) |
| constant | -0.000253 | -0.000617 | 0.000148 | -0.000262 |
| | (-0.68) | (-0.97) | (1.49) | (-1.44) |
| Observations (firms) | 88 | 88 | 88 | 88 |
| Adj. $R^2$ | 0.812 | 0.838 | 0.828 | 0.899 |

Notes: Robust standard errors clustered by sector and *t*-statistics reported in parentheses; ***p<0.01, **p<0.05, *p<0.10. The sample consists of the 88 listed UK firms that (1) voluntarily disclose GHGE data in 2012, and (2) respond to the Reputation Risk question in the CDP survey in 2012. ΔX is measured as changes from average values from the pre-MCR period to the post-MCR period. All variables are defined in Appendix A.

## Internet Appendix Table I: Robustness

This table reports the results of my robustness tests. *N* equals the number of observations, *Treat* x *Post* is the variable of interest. Robust standard errors clustered by country in parentheses; ***, **, and * denote statistical significance at the 1%, 5%, and 10% level, respectively.

To address concerns that non-EU firms are driving the results, the first test uses UK firms and EU firms only; the inferences are unchanged. In the second test, I use unlogged *GHG_Level* and *GHG_Intensity* as the dependent variables and continue to find similar results.

| Robustness Test | N | Treat x Post | Treat x Post |
|---|---|---|---|
| | | *GHG_Level* | *GHG_Intensity* |
| Table 5: Unlogged dependent variables | 4,387 | -1,690,306**<br>(-2.19) | -0.00016*<br>(-1.78) |
| Table 5: UK and EU firms only | 3,289 | -0.196**<br>(-2.27) | -0.159*<br>(-1.89) |

## Internet Appendix Table II: Greenhouse gas emission regulations around the world

| | Country | Year law passed | Year law came into effect | Type of mandate | Firms affected | Description | Include/ Exclude from sample | Reason for inclusion/exclusion |
|---|---|---|---|---|---|---|---|---|
| 1 | Australia | 2011 | 2012 | Carbon tax | All organizations | On July 1, 2012, Australia introduced a carbon tax on organizations at $19.60 USD/ton of CO2. The tax was repealed two years later on July 17, 2014.[1] | Exclude | Mandate imposes explicit incentives for firms to reduce GHG, and overlaps with sample period. |
| 2 | Australia | 2007 | 2008 | GHG disclosure | Large emitters | Companies with emissions in excess of 125,000 tons of CO2 equivalent/annum are required to report energy usage and GHG to the Government under the National Greenhouse and Energy Reporting Act.[2] | Exclude | Australia is omitted from potential control firms due to the Australian carbon taxation (see item #1). |
| 3 | Bulgaria | 2015 | 2016 | Carbon tax | Large emitters that operate in Bulgaria | Large companies with emissions in excess of 150,000 tons of CO2 equivalent/annum are subject to the country's carbon tax.[3] | Exclude | Law imposes explicit incentives for firms to reduce GHG, and overlaps with sample period. |
| 4 | Canada | 1995 | 1999 | Emissions disclosure | Large emitters | Companies covered by the Canadian Environmental Protection Act must report information on pollutant emissions to the National Pollutant Release Inventory. Large emitters must additionally report GHG to the Canadian GHG Reporting Program.[4] | Include | Mandate relates to GHG but came into prior to the sample period. As such, any effect on emissions would likely stabilize prior to the start of the sample period. |
| 5 | Chile | 2015 | 2017 | Carbon tax | Companies incorporated in Chile | Chile introduced a tax on CO2 emissions from sources with a thermal power of 50MW of more.[5] | Exclude | Law imposes explicit incentives for firms to reduce GHG, and overlaps with sample period. |
| 6 | Colombia | 2016 | 2017 | Carbon tax | All companies operating in Colombia | The law subjects Colombian companies to a carbon tax but allows corporate tax deductions from renewable energy sources.[6] | Exclude | Law imposes financial incentives to reduce GHG and overlaps with sample period. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 7 | European Union | 2001 | 2005 | Cap-and-trade | Power generation and manufacturing | The European Union Emission Trading Scheme (or EU ETS) is the largest emissions trading scheme in the world. The EU ETS operates in every EU nation and focuses on emissions from power generation and manufacturing.[7] | Exclude | Mandate imposes explicit incentives to reduce GHG. Although EU ETS came into effect prior to the sample period, several changes occurred throughout the sample period, both in the U.K. and other EU nations. |
| 8 | Finland | 1985 | 1990 | Carbon tax | Individuals and certain sectors | A carbon tax was enacted in 1990; the current tax is approximately $24.39 USD per ton of CO2 equivalent.[8] | Include | Mandate imposes explicit incentives to reduce GHG, but came into effect several years prior to the sample period. |
| 9 | Ireland | 2008 | 2010 | Carbon tax | All organizations | Ireland's carbon tax (€20/ton since 2012) covers fossil fuels consumed by homes, offices, vehicles and farms and not already covered by the EU ETS.[9] | Exclude | Mandate imposes explicit incentives for firms to reduce GHG, and overlaps with sample period. |
| 10 | Japan | 2008 | 2010 | Cap-and-trade | Top 1,400 emitters | The largest 1,400 emitters in Tokyo are required to cut GHG by 6%-8%, otherwise the firms must buy emission allowances, or invest in renewable energy certificates and offset credits. In the second phase of the scheme (2015-2019), target reductions were increased to 15%-17%.[10] | Exclude | Mandate imposes explicit incentives for firms to reduce GHG, and overlaps with sample period. |
| 11 | Japan | 2005 | 2006 | Emissions disclosure | Large emitters | The Mandatory Greenhouse Gas Accounting and Reporting System requires large emitters to report GHG to the Government.[11] | Exclude | Japan is excluded due Item #10. |
| 12 | New Zealand | 2009 | 2010 | Cap-and-trade | Certain sectors | NZ Emissions Trading Scheme covers forestry, energy, industry and waste. Covered firms must provide one emission unit for every two tons of CO2 equivalent emitted, or buy additional units from the Government.[12] | Exclude | Mandate imposes explicit incentives for firms to reduce GHG, and overlaps with sample period. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 13 | Singapore | 2016 | 2017 | Mandated energy efficiency requirements | Large emitters in Singapore | Large energy consumers must report energy use, GHG and energy efficiency improvement plans to the Government.[13] | Exclude | Act imposes mandated energy efficiency requirements and reporting and overlaps with the sample period. |
| 14 | South Africa | 2017 | 2018 | Emissions disclosure | Large emitters | National Greenhouse Gas Emission Reporting Regulation introduced in South Africa to maintain a National Greenhouse Gas Inventory for large emitters.[14] | Exclude | Mandate relates to GHG disclosure and overlaps with sample period. |
| 15 | South Korea | 2009 | 2011 | Emissions disclosure | Large emitters | South Korea's Basic Act on Low Carbon Green Growth requires energy-intensive companies to report emissions and energy consumption to the Government.[15] | Exclude | Mandate relates to GHG and overlaps with sample period. |
| 16 | South Korea | 2015 | 2016 | Cap-and-trade | Certain sectors | South Korea's national Emissions Trading Scheme covers 525 entities from 23 sectors.[16] | Exclude | South Korea excluded due Item 15. |
| 17 | Sweden | 1985 | 1991 | Carbon tax | Individuals and certain sectors | Sweden introduced a carbon tax on individuals and certain sectors at $133 USD/ton of CO2 equivalent.[17] | Include | Mandate imposes explicit incentives to reduce GHG, but came into effect several years prior to the sample period. |
| 18 | Switzerland | 2006 | 2008 | Emissions trading scheme | Large, energy-intensive entities | The Swiss ETS is mandatory for large, energy-intensive firms and covers about 10% of Switzerland's total GHG.[18] | Exclude | Mandate imposes explicit incentives for firms to reduce GHG, and overlaps with sample period. |
| 19 | United Kingdom | 2012 | 2013 | Emissions disclosure | Listed | Listed companies to report annual GHG from 2013. UK is first country to mandate inclusion of GHG data in financial reports.[19] | N/A | N/A - this is the mandate under study |
| 20 | United States | 2008 | 2009 | Emissions disclosure | Large emitters | Mandatory Reporting of Greenhouse Gases Rule covers large GHG emitters in the United States. Facilities emitting at least 25,000 metric tons of CO2 equivalent/annum must disclose GHG data annually to the EPA.[20] | Exclude | Mandate relates to GHG and overlaps with sample period. |

Sources:

[1] https://www.abc.net.au/news/2014-07-10/carbon-tax-timeline/5569118
[2] https://www.oecd.org/daf/inv/investment-policy/WP-2012_1.pdf (page 14)
[3] https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/689330/EPRS_BRI(2021)689330_EN.pdf (page 1)
[4] http://iri.hks.harvard.edu/files/iri/files/corporate_social_responsibility_disclosure_3-27-15.pdf (page 3)
[5] https://www.climate-laws.org/legislation_and_policies.csv
[6] https://gnarlytreesustainability.com/wp-content/uploads/2022/07/Case-5_Colombia.pdf (page 1)
[7] https://climate.ec.europa.eu/system/files/2016-12/factsheet_ets_en.pdf (page 1)
[8] https://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2015/05/FINLAND.pdf
[9] https://www.iea.org/policies/1721-ireland-carbon-tax
[10] https://icapcarbonaction.com/system/files/ets_pdfs/icap-etsmap-factsheet-51.pdf
[11] https://www.greenfinanceplatform.org/policies-and-regulations/japans-mandatory-greenhouse-gas-accounting-and-reporting-system#:~:text=Japan's%20Mandatory%20Greenhouse%20Gas%20Accounting%20and%20Reporting%20System%20requires%20specified,the%20results%20to%20the%20Government
[12] https://environment.govt.nz/what-government-is-doing/areas-of-work/climate-change/ets/about-nz-ets/
[13] https://www.nccs.gov.sg/singapores-climate-action/mitigation-efforts/carbontax/
[14] http://iri.hks.harvard.edu/files/iri/files/corporate_social_responsibility_disclosure_3-27-15.pdf (page 11)
[15] https://www.oecd.org/daf/inv/investment-policy/WP-2012_1.pdf (page 14)
[16] https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems%5B%5D=47
[17] https://blogs.ubc.ca/realmelo/2013/03/06/a-quick-look-at-swedens-carbon-tax/
[18] https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems%5B%5D=64
[19] https://iri.hks.harvard.edu/files/iri/files/corporate_social_responsibility_disclosure_3-27-15.pdf (page 14)
[20] https://iri.hks.harvard.edu/files/iri/files/corporate_social_responsibility_disclosure_3-27-15.pdf (page 15)