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Firm-Value Effects of Carbon Emissions and Carbon Disclosures

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ABSTRACT: Using hand-collected carbon emissions data for 2006 to 2008 that were voluntarily disclosed to the Carbon Disclosure Project by S&P 500 firms, we examine the effects on firm value of carbon emissions and of the *act* of voluntarily disclosing carbon emissions. Correcting for self-selection bias from managers' decisions to disclose carbon emissions, we find that, on average, for every additional thousand metric tons of carbon emissions, firm value decreases by $212,000, where the median emissions for the disclosing firms in our sample are 1.07 million metric tons. We also examine the firm-value effects of managers' decisions to disclose carbon emissions. We find that the median value of firms that disclose their carbon emissions is about $2.3 billion higher than that of comparable non-disclosing firms. Our results indicate that the markets

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penalize all firms for their carbon emissions, but a further penalty is imposed on firms that do not disclose emissions information. The results are consistent with the argument that capital markets impound both carbon emissions and the act of voluntary disclosure of this information in firm valuations.

Keywords: *GHG emissions*; *voluntary disclosures*; *firm value*.

JEL Classifications: *G14*; *Q51*; *M14*.

Data Availability: *Data are available from the sources identified in the study*.

I. INTRODUCTION

Interest in climate-change risk from institutional investors and various other stakeholders has grown 18-fold in the past decade (PricewaterhouseCoopers 2012, 6) and some sell-side analysts are integrating the financial implications of carbon emissions into their investment recommendations (Eccles, Krzus, and Serafeim 2011). Some observers predict that concern about the relationship between carbon or greenhouse gas (GHG) emissions and global climate change will drive a redistribution of value from firms that do not control carbon emissions successfully to firms that do (GS Sustain 2009, 1). Despite this heightened interest, there is little research regarding the association between carbon emissions, their disclosures, and firm value. Motivated by concern about climate-change risk and carbon emission levels as expressed by investors, regulators, standard-setters, and other stakeholders, we estimate the effects on firm value of carbon emissions and of the *act* of voluntarily disclosing carbon emissions.

Our inquiry is important because recent major initiatives exert pressure on U.S. and non-U.S. firms to increase transparency through disclosures of new nonfinancial climate change and environmental information, including carbon emissions. These initiatives stem from organizations such as the Carbon Disclosure Project (CDP), Ceres, the Global Reporting Initiative (GRI), the Investor Network on Climate Risk (INCR), and the International Integrated Reporting Committee (IIRC).[1] Thus, corporate managers also face growing shareholder pressure to evaluate and report on the risks and opportunities their companies face with respect to climate change, including the exposure of their firms to regulatory and market influences. Notably, climate-change-related shareholder resolutions, as a percentage of all shareholder resolutions, grew from 14 percent in 2004 to 27 percent in 2009 (Ernst & Young 2011).

A firm's enhanced reputation for environmental responsibility, such as investing in renewable energy alternatives that reduce carbon emissions, can potentially bring economic benefits from the broader stakeholder community. These benefits include increased revenues; positive perceptions of employees, customers, suppliers, and other stakeholders who identify the corporation with its environmentally friendly side (Simnett, Nugent, and Huggins 2009a), a more talented and committed work force (Castelo Branco and Lima Rodrigues 2006), and fewer potential claimants on the firm's rents through fines or other compliance costs (Sharfman and Fernando 2008). Collectively, pressure from shareholders and outside organizations creates an impetus for internal management control systems to collect and analyze climate-change-related information, to disclose

[1] The CDP, an independent not-for-profit organization acting on behalf of hundreds of institutional investors, holds the largest repository of carbon emissions information. Ceres is a national network of investors, environmental organizations, and other public interest groups working with companies and investors to address sustainability challenges such as global climate change. The Global Reporting Initiative (GRI) developed what is now the most widely used sustainability reporting framework around the world. The IIRC brings together a cross-section of representatives from the corporate, accounting, securities, regulatory, NGOs, and standard-setting sectors responsible for individual elements of reporting.

it, and to understand the financial consequences of decisions related to climate change as well as broader sustainability issues (Institute of Chartered Accountants in England and Wales 2004).[2] Thus, even though there are no explicit costs to firms for emitting GHG in the U.S., evidence on the extent to which capital markets incorporate carbon emissions into firm valuation will help U.S. firms make important decisions regarding the broad cost-benefit trade-offs of allocating resources to carbon emissions-reduction initiatives (Thaler and Sunstein 2009).[3]

Our study also lends insight into matters addressed by U.S. and international accounting standard-setters and regulators. For example, in January 2010, the SEC responded to investors' concerns about required climate-change-related disclosures by providing explicit guidance on disclosures of risks and opportunities related to climate change in SEC regulatory filings. In conjunction with this guidance, SEC Commissioner Elisse Walter expressed concern that "many public companies are in fact providing disclosure about significant climate-change-related matters through mechanisms outside of the disclosure documents they file with the Commission."[4] Indeed, the International Auditing and Assurance Standards Board (IAASB) recently approved ISAE 3410, Assurance Engagements on Greenhouse Gas Statements, which provides guidance for independent assurance on GHG statements issued by U.S. and international firms (International Auditing and Assurance Standards Board [IAASB] 2012).[5] According to the IAASB, the independent assurance can be provided to report on an entity's GHG statement prepared: "(a) As part of a regulatory disclosure regime; (b) As part of an emissions trading scheme; or (c) To inform investors and others on a voluntary basis" (IAASB 2012, para. 1).

Extant accounting research reports that capital markets use environmental disclosure/liability information in assessing how well firms manage exposure to environmental risk (Barth and McNichols 1994; Blacconiere and Patten 1994; Cormier and Magnan 1997; Campbell, Sefcik, and Soderstrom 1998). These papers examine environmental disclosures mandated by government agencies such as the U.S. Environmental Protection Agency (EPA) and the Canadian Environment Ministries, or by financial reporting regulations, and the disclosures pertain to toxic substances with well-identified risks. In contrast, carbon emissions have ill-defined risks; further, disclosure of carbon emissions is voluntary. Other related research examines the market-value relevance of excess emissions allowances within the context of the enacted sulfur dioxide (SO_2) emissions trading scheme (ETS) in the U.S. (Hughes 2000; Johnston, Sefcik, and Soderstrom 2008).[6] SO_2 emissions measurement involves highly accurate continuous emissions monitoring (CEM) systems, reporting of these emissions in the U.S. is mandatory, and SO_2 emission allowances are traded in the market. It follows that, unlike the measurement uncertainty inherent in carbon emissions,[7] there

2 Emissions from various greenhouse gases are expressed in carbon-dioxide equivalents (CO_2-e) based on their global warming potential. The Environmental Protection Agency (EPA) has concluded that the more carbon emissions there are in the atmosphere, the more heat is trapped. This leads to rising temperatures and, thus, climate change. Source: http://www.epa.gov/climatechange

3 For example, Microsoft recently announced that it has established an internal "price" for carbon as part of its drive to become carbon-neutral (Vagus 2012). The company has determined its own carbon price based on the cost of buying offsets, whereby the entity pays for decreasing another entity's emissions or increasing another entity's removals, compared to a hypothetical baseline, and the price of investing in renewable energy.

4 Commissioner Walter's full speech is available at: http://www.sec.gov/news/speech/2010/spch012710ebw-climate.htm

5 The standard, approved in March 2012, is effective for assurance reports covering periods ending on or after September 30, 2013.

6 The EPA states, "The Clean Air Act requires the EPA to set national ambient air quality standards (NAAQS) for sulfur dioxide and five other pollutants considered harmful to public health and the environment (the other pollutants are ozone, particulate matter, nitrogen dioxide, carbon monoxide, and lead)." Source: http://www.epa.gov/ttn/naaqs/standards/so2/s_so2_index.html

7 Measurement of carbon emissions often involves estimation. The EPA provides guidance for such estimation at http://www.epa.gov/climateleadership

is little uncertainty about the nature, measurement, and magnitude of the cost of SO_2 emissions. Furthermore, findings in Hughes (2000) and Johnston et al. (2008) are based on small samples and/or a few industries.

Unlike toxic emissions, during the period of our study carbon emissions were largely unregulated in the U.S. and firms were not required to disclose them. Accounting research on the market-value relevance of voluntarily disclosed carbon emissions is rare. Using a sample of 58 publicly traded Australian firms expected to be affected by a proposed national ETS, Chapple, Clarkson, and Gold (2013) find that the markets penalize firms that will be affected by the proposed ETS. However, they only study firms that disclose emissions and do not address how the capital markets integrate both carbon emissions and the act of voluntary disclosure of this information into firm valuations.

Our study adds to extant accounting research by examining the effect of carbon emissions on firm value after correcting for self-selection bias, as well as the effect on firm value of the act of voluntarily disclosing carbon emissions. We hand-collect carbon emissions data for 2006 to 2008 for S&P 500 firms to investigate the hypothesis that firm value is negatively associated with carbon emissions. We obtain all carbon emissions data publicly available from CDP, about 40 percent of our sample. We also divide our sample based on whether firms will be subject to the EPA's GHG Mandatory Reporting Rule (Environmental Protection Agency [EPA] 2009).[8] Because firms in our sample period choose to disclose their carbon emissions, we correct for self-selection bias by incorporating systematic firm- and industry-level characteristics in our analyses.

We find that, on average, for each additional thousand metric tons of carbon emissions for our sample of S&P 500 firms, firm value decreases by $212,000.[9] This translates into a firm-value penalty of $1.4 billion for firms in the third quartile in terms of carbon emissions relative to firms in the first quartile.[10]

We conduct several sensitivity tests to assess the robustness of our main results and our inferences are unchanged. These tests include estimating the effects of carbon emissions on firm value using the Ohlson (1995) model, and estimating the relationship between changes in firm value and changes in carbon emissions. In two additional tests, we use December fiscal year-end firms only,[11] and also control for the effects of other unbooked liabilities to rule them out as alternative explanations for our main results.

Our finding of a negative association between carbon emissions and firm value begs the question, "If the capital markets penalize firms for their carbon emissions, then why do firms choose to disclose information on them?" We argue that managers weigh the costs and benefits of disclosing carbon emissions and choose to disclose only when the perceived benefits of doing so outweigh the perceived costs. Therefore, we also examine the firm-value effects of the act of voluntarily disclosing carbon emissions. Using propensity score matching (Rosenbaum 2005) and doubly robust regression (Imbens and Wooldridge 2007), we find that the median market value of firms that disclose their carbon emissions is about $2.3 billion higher than that of their non-disclosing counterparts. The median market value of the sample disclosing firms is

[8] The EPA's Greenhouse Gas Mandatory Reporting Rule requires fossil fuel and industrial gas suppliers, direct GHG emitters, and manufacturers of heavy-duty and off-road vehicles and engines to report their GHG emissions to the EPA, beginning with carbon emissions for 2010.

[9] To provide some perspective on this number, we note that the net present value of $17 per metric ton of carbon emissions discounted in perpetuity at an interest rate of 8 percent is approximately $212 (that is, $212,000 per thousand metric tons of carbon emissions).

[10] The median emissions for our sample firms are 1.07 million metric tons.

[11] The carbon emissions data are for calendar year *t*, while our accounting data are for fiscal year *t*. A majority of our sample firms have a December fiscal year-end, so to minimize the effects of different fiscal and calendar year-ends, we also conduct analyses including only firms that have a December fiscal year-end.

approximately $16 billion. These results, combined with our main result of a negative association between carbon emissions and firm value, are consistent with the argument that capital markets impound both carbon emissions and the act of voluntary disclosure of this information in firm valuations. While all firms are penalized for their carbon emissions regardless of whether they disclose them, firms that do not disclose their carbon emissions face a further capital market penalty.

Our study contributes to the accounting literature in four distinct and important ways. First, extant accounting research examines nonfinancial mandated environmental disclosures involving relative certainty regarding the nature, measurement, and magnitude of the cost of the emissions. Examples include studies of SO_2 emissions by Hughes (2000) and Johnston et al. (2008), or financial accounting information associated with measurement uncertainty that affects estimation of reported accounting numbers for Superfund liabilities (Campbell, Sefcik, and Soderstrom 2003). In contrast, we focus on carbon emissions, which are largely unregulated in the U.S. but involve significant climate-change risk.[12] There is considerable uncertainty about the measurement and reporting of carbon emissions, which are currently disclosed at management's discretion in the U.S. Our study provides empirical evidence concerning the extent to which investors incorporate often unassured, uncertain nonfinancial information in their firm-value assessments. Further, our study provides evidence on the extent to which the markets use environmental information from sources other than regulatory agencies for firm valuation.

Second, we examine the relation between carbon emissions and firm value for disclosing and non-disclosing firms, correcting for self-selection bias associated with managers' decisions to disclose carbon emissions. To our knowledge, this is the first study that does so. Third, our paper is the first to investigate the relation between the magnitude of carbon emissions and firm value and estimate the price that U.S. capital markets are imputing to carbon emissions. Fourth, our study provides empirical evidence of a firm-value penalty for non-disclosing firms. To our knowledge, this is the first study to provide empirical evidence on the firm-value effects of *both* the decision to voluntarily disclose carbon emissions *and* the magnitude of carbon emissions.

We next review the literature and develop our hypothesis. Sections III and IV present our research design and results, respectively, and Section V concludes the paper.

II. INSTITUTIONAL CONTEXT, THEORY, AND HYPOTHESIS

U.S. firms face increasing pressure from various stakeholders, including investors, financial risk managers, insurance companies, carbon traders, and NGOs, to measure, disclose, monitor, and manage their carbon emissions (Fornaro, Winkelman, and Glodstein 2009). Other potential carbon-related costs include capital expenditures resulting from environmental initiatives, such as acquiring or developing less carbon-intensive technologies and processes, research and development to develop goods and services associated with lower carbon emissions, and other corporate initiatives such as reducing employees' carbon footprint. Carbon emissions have also become an essential element in analyzing a company's risk profile, potential "unbooked" liabilities and costs without lasting economic benefits (such as fines, penalties, and awards from lawsuits), and firms' financial performance. For instance, Standard & Poor's downgraded the debt of a large U.K. power-generating company, Drax, owing in part to future business risks from new European emissions trading rules that are expected to increase carbon costs (Barley 2009).

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[12] Climate-change risk encompasses risks driven by: changes in regulation, changes in physical climate parameters, and changes in other climate-related developments (see https://www.cdproject.net/CDP%20Questionaire%20Documents/Investor-CDP-2013-Information-Request.pdf).

Some stakeholders advocate a tax on carbon emissions or an emissions allowance system. To put such potential direct costs in perspective, on average, S&P 500 firms emit 382 tons of carbon dioxide-equivalent, CO_2-e, for every U.S. $1 million of revenue that they generate (Investor Responsibility Research Center Institute [IRRCi]/Trucost Report 2009). If the Report's suggested market price of $28.24 were applied to each ton of CO_2-e emitted by the S&P 500 firms, then carbon emission costs would total over $92.8 billion, or 1.08 percent of revenue from the companies in 2007, and 5.5 percent of earnings before interest, tax, depreciation, and amortization (IRRCi/Trucost Report 2009).

Theory and Hypothesis

Accounting research on the value relevance of firms' environmental disclosures falls into three broad categories. The first includes studies examining the market valuation of environmental disclosures that are mandated either by accounting standards (Barth and McNichols [1994], Blacconiere and Patten [1994], and Campbell et al. [1998] on Superfund liabilities), or by the government (Hughes [2000] and Johnston et al. [2008] on sulfur dioxide [SO_2] emissions; Cormier and Magnan [1997] on water pollution; and Connors, Johnston, and Silva-Gao [2013] on TRI valuation).[13] The first subset of these studies focuses on the extent to which the markets view as adequate the amounts recognized by firms for Superfund-related liabilities.

The second subset in the first category examines the market-value relevance of excess emission allowances for the SO_2 ETS in the U.S. (Hughes 2000; Johnston et al. 2008). Hughes (2000) examines the firm-value effects of SO_2 emissions using a sample of publicly traded electric utilities targeted as high-polluting by the 1990 Clean Air Act Amendments (CAAA). He finds that the market penalizes the high-polluting utilities during 1989 to 1991, the years that are most likely associated with new CAAA compliance costs. Johnston et al. (2008) extends Hughes (2000) by examining the value relevance of SO_2 emission allowances held by publicly traded U.S. electric utilities, which are subject to the 1990 CAAA ETS. The authors find support for their reasoning that emission allowances above a firm's current needs have two components—an asset value and a real option value—that will be valued by the market.

Unlike the institutional context of our study in which carbon emissions are measured or estimated and disclosed voluntarily, SO_2 emissions are measured using highly accurate CEM systems, reporting of SO_2 emissions in the U.S. is mandatory, and SO_2 emission allowances are traded in the market. It follows that there is relative certainty about the nature, measurement, and magnitude of the cost of SO_2 emissions. Although the findings in Hughes (2000) and Johnston et al. (2008) are based on small samples and/or a few industries, the results of these studies are consistent with a negative association between electric utilities' SO_2 emissions and market value.

The second broad category examines the market valuation of environmental capital expenditures (Clarkson, Li, and Richardson 2004; Cho, Freedman, and Patten 2012). Using a sample from the pulp and paper industry for 1989 to 2000, Clarkson et al. (2004) examine the market valuation of environmental capital expenditures conditional on the firms' environmental performance. They predict and find that the market places a positive value on environmental expenditures for low-polluting firms, but assigns no value to the environmental expenditures of high-polluting firms. Further, they find that investors use disclosures of environmental capital expenditures to assess unbooked environmental liabilities for high-polluting firms. More recently, Cho et al. (2012) use a sample of *Fortune* 500 firms operating in industries subject to the EPA's

[13] The EPA collects data annually from facilities that release or transfer certain toxic chemicals. The Toxics Release Inventory (TRI) data are available on the EPA website (http://www.epa.gov/tri/triprogram/whatis.htm).

TRI program, and find that companies use the disclosure of environmental capital spending as a strategic tool to address their exposure to political and regulatory concerns.

The third broad category examines more recent research on the market valuation of *voluntarily* disclosed carbon emissions. Chapple et al. (2013) examine the association between a dichotomous measure of high- and low-carbon emissions intensity and the market value of equity for a sample of 58 publicly traded Australian firms originally subject to a proposed national ETS. Using a modified Ohlson (1995) valuation model, the study finds that carbon-intense firms suffer a penalty of 6.57 percent of market capitalization. However, the study does not account for the voluntary nature of the firms' carbon emission disclosures or for potential self-selection bias during the sample period of 2006 to 2009. Further, unlike our sample of S&P 500 firms, the more carbon-intensive firms in their sample are generally smaller, less profitable, and riskier than their less carbon-intensive counterparts.[14]

Walley and Whitehead (1994, 47) argue that "[i]n a world where [managers] cannot do everything, only a value-based approach allows informed trade-offs between [environmental] costs and benefits." Our research addresses this point by examining the effect of carbon emissions on firm value after correcting for self-selection bias associated with managers' decisions to voluntarily disclose carbon emissions. Moreover, we estimate the effect on firm value of disclosing carbon emissions.

We draw on value relevance research (Barth, Beaver, and Landsman 2001; Holthausen and Watts 2001) as a theoretical framework for assessing whether a nonfinancial environmental performance metric in the form of carbon emission levels provides information that investors use for firm valuation. Based on this research, we posit that if capital markets believe that carbon emissions are relevant for valuation and are measured reliably enough, carbon emission levels will have significant market-value implications (Barth et al. 2001).

Although carbon emissions information is self-reported and frequently unassured, it may nevertheless be reasonably credible. First, the markets can assess the credibility of the data by comparing them to similar data from other firms in the same industry, and some of the data may be assured. Some firms operate in jurisdictions such as the European Union, where emissions are regulated. Second, although responding to the CDP questionnaire is voluntary, once a firm decides to participate, it is significantly more likely to participate in the future (Stanny 2013). These repeated interactions between the CDP and the firm will generally increase the cost of reporting untruthfully, particularly as more firms in the industry decide to report and assurance of emissions becomes more widespread. Untruthful reporting that is eventually revealed can damage the firm's overall reporting credibility and expose it to litigation risk.

Market-value penalties associated with carbon emissions reflect first, the perceived relationship between carbon emission levels and the firms' climate change related risk profile. This risk is driven by climate change regulation, uncertainty surrounding new regulatory compliance, and uncertainty surrounding physical climate parameters, such as severe weather (Epstein 2008, 62). The second source of market-value penalty is the cost of measuring, disclosing, monitoring, and reducing carbon emissions. According to natural-resource-based theory (Hart 1995), a firm's key resources and capabilities affect its ability to sustain its competitive advantage. This argument points to the importance, for firm valuation, of cost-benefit trade-offs of allocating resources to carbon emissions reduction initiatives (Thaler and Sunstein 2009). It follows that firms that do not integrate climate change risk into their business strategy (e.g., by investing in renewable energy alternatives that reduce carbon emissions) are likely to lower investors' market-value expectations relative to firms

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[14] Finally, a few other studies examine factors that affect firms' decisions to adopt proactive environmental strategies (Clarkson, Li, Richardson, and Vasvari 2011), and whether corporate social performance enhances financial performance (Dhaliwal, Li, Tsang, and Yang 2011; also, see a literature review by Clarkson [2012]).

that do (Hart 1995; Epstein 2008, 145). Consistent with these arguments, we propose the following hypothesis (in alternative form) regarding the firm-value effect of carbon emissions:

H1: Firm value is negatively associated with carbon emissions.

There are at least two reasons why our hypothesis may not obtain. First, carbon emissions meet the definition of an externality. There is currently a great deal of uncertainty regarding the extent to which U.S. firms will be required to internalize the cost of their carbon emissions in the future. In turn, the market is likely to reflect such uncertainty in valuing future liabilities from carbon emissions. Also, firms may be able to pass along the cost of their carbon emissions to their consumers and/or supply chain partners (Initiative for Global and Environmental Leadership [IGEL]/Knowledge@Wharton 2012), thus reducing the firms' share of the costs of carbon emissions.[15] Second, if the capital markets view voluntarily disclosed carbon emissions as insufficiently reliable (Barth et al. 2001), then they may disregard this information when making firm-value assessments (Simnett, Vanstraelen, and Chua 2009b). Despite these considerations, the results of Hughes (2000), Johnston et al. (2008), and Chapple et al. (2013), as discussed above, lead us to predict a negative association between carbon emissions and firm value.

Firm-Value Effects of Decision to Disclose Carbon Emissions

If the capital markets penalize firms for their carbon emissions, then why do firms choose to disclose them? In general, disclosures provide benefits through reduced information asymmetry between the firm and outsiders, including its investors, thus facilitating efficient allocation of scarce resources (Healy and Palepu 2001). Firms making truthful voluntary carbon emission disclosures deliver transparent nonfinancial information to investors that informs them of future costs that may be imposed upon the firm due to its carbon emissions. If firms do not disclose carbon emissions, then investors will not only impute the firms' carbon emissions, but also likely treat non-disclosure as an adverse signal and penalize non-disclosing firms (Milgrom 1981). Also, investors are likely to undertake costly information searches regarding the non-disclosers' emissions, thus increasing costs to investors and, ultimately, the firms' costs (Johnston 2005). Research on voluntary corporate social responsibility (CSR) disclosures documents that firms that issue CSR reports experience a decrease in their cost of capital if the firms show superior CSR performance (Dhaliwal et al. 2011).[16] Voluntary disclosures are also used to reduce potential regulatory intervention (Blacconiere and Patten 1994).

Furthermore, the act of disclosure itself, even in the absence of mandated behavioral changes, can be associated with beneficial consequences from the investors' viewpoint. For example, an unintended benefit of the TRI disclosure rule under the Emergency Planning and Community Right to Know Act was a large reduction in toxic emissions in the U.S. (Thaler and Sunstein 2009). Environmentally concerned groups tend to target the worst TRI offenders, thus producing an "environmental blacklist." Consistent with Thaler and Sunstein's (2009) concept of "social nudge," firms seek to avoid appearing on such a list because the ensuing bad publicity could lower the company's market value. Therefore, companies that end up on the list are motivated to take steps to

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15 Nevertheless, firms with lower carbon costs will have a competitive advantage through lower total costs, *ceteris paribus*.

16 Although both Dhaliwal et al. (2011) and our paper include an examination of voluntary disclosures, we also analyze the firm-value effect of the magnitude of carbon emissions. This information is much more precise with respect to carbon emissions than the binary environmental performance measures of strengths and weaknesses on particular components used in Dhaliwal et al. (2011). Further, their paper describes only rewards (in the form of lower cost of equity) for disclosing positive news (CSR reports), and does not discuss the cost of disclosing *per se*.

reduce their TRI in order to be removed from the list, and the companies not yet on the list are motivated because they want to ensure that they do not end up there. Although carbon disclosures are voluntary, firms face considerable pressure to disclose their emissions. Hence, similar motivations exist for disclosers to reduce their carbon emissions. Moreover, a firm that discloses its carbon emissions signals its ability to measure its emissions, a prerequisite for managing them. This discussion suggests that the markets will reward the firms that disclose their carbon emissions.

Moser and Martin (2012, 804) argue that viewing CSR activities and related disclosures more broadly as being motivated by shareholders and non-shareholders alike raises issues that do not fall within the traditional perspective of shareholder value maximization. This argument implies that it is likely that allocation of scarce corporate resources to some CSR investments, such as measuring and disclosing carbon emissions, is made *at the expense* of shareholders. For instance, carbon emission disclosures can impose proprietary costs on some firms (Li, Richardson, and Thornton 1997). Also, government regulators such as the EPA can use disclosures by high-carbon-emitting firms as grounds for investigations that can ultimately increase those firms' compliance costs. Furthermore, carbon emissions disclosures could invite costly litigation by previously uninformed victims of GHG-related climate change, benefit competitors' green-marketing strategies aimed at environmentally conscious consumers, and provide ammunition for public interest groups (e.g., Ceres) to press for stricter regulation. In summary, under some circumstances the markets will penalize firms that voluntarily disclose their carbon emissions.

Because the answer to the question, "Why do firms choose to disclose their carbon emissions?" is not self-evident in the context of this study, we address the question by examining the firm-value effects of the act of voluntarily disclosing carbon emissions. By investigating whether the markets reward or penalize voluntary disclosers of carbon emissions, we provide insights on the two perspectives discussed above.

III. RESEARCH DESIGN

Sample and Data

Our sample consists of all S&P 500 firms for the three-year period 2006 to 2008. We choose 2006 as the initial year because the S&P 500 firms were first included as a group in the 2007 CDP report, which provides 2006 data. We choose 2008 as our final year because in April 2009 the EPA issued a proposed rule on GHG mandatory reporting that became effective on December 29, 2009 requiring reporting of carbon emissions for 2010 and thereafter (EPA 2009).[17] To avoid confounding voluntary disclosure to the CDP with the transition to the EPA's mandatory reporting rule, we exclude 2009 data. In order to maintain a constant sample over this period we use firms that were included in the S&P 500 index on December 31, 2007.

We hand-collect carbon emissions data from 2006 to 2008 from the CDP database.[18] The CDP requests information from the world's largest companies as measured by market capitalization. Currently, the CDP acts on behalf of 665 institutional investors representing more than $78 trillion

[17] The original reporting deadline of March 30, 2011 for 2010 was extended to September 30, 2011.

[18] This entailed manually collecting and cross-validating carbon emissions numbers from data purchased from the CDP with *individual* firm responses available at the CDP website for all S&P 500 firms for our three-year period. We found numerous discrepancies between the data in the individual firm responses and the CDP's annual summary reports on S&P 500 firms, usually because the summaries only report data available up to the point when the summaries were prepared. For example, the summary report for a given year could show a firm as "not responding," while the CDP website would show the firm as responding in that year. These discrepancies imply that caution should be used in relying exclusively on the CDP annual summary reports.

in assets under management.[19] The number of firms answering the CDP survey increased from 235 in 2003 to more than 3,000 companies in 2011, including 81 percent of the Global 500 firms and 68 percent of the S&P 500 firms. PricewaterhouseCoopers LLP has been the global sponsor of the CDP since 2008, with responsibility for analyzing the survey responses for the S&P 500, Global 500, and FTSE 600 companies.[20]

The CDP questionnaire elicits information on carbon emissions in metric tons, energy, and trading.[21] Participation in the CDP questionnaire is voluntary and different sets of firms (1) do not respond or respond indicating their decision to decline participation; (2) provide partial information, such as links to information generally available at the firm's website, for instance their CSR reports, without answering the questionnaire; (3) respond to the questionnaire but allow the CDP to make the responses available only to institutional investors who are signatories of the CDP; and (4) respond to the questionnaire and allow the CDP to make the responses publicly available.

Table 1 provides the S&P 500 firms' responses to the CDP questionnaire and carbon emissions for the years 2006 to 2008. Of the total sample, 550 firm-years (38.12 percent) reflect responses that firms allow to be publicly available, and 184 firm-years (12.75 percent) reflect responses by firms that do not allow their responses to be made public. Further, 205 firm-years (14.21 percent) come from firms that provide only partial information to the CDP. As explained in Table 1, footnote c, for 35 firm-years we were able to obtain carbon emissions data from the firms' responses to the CDP questionnaire in a subsequent year. In total, we obtained carbon emissions data for 584 firm-years of 1,443 firm-year observations, or 40.47 percent, representing 256 firms. The disclosures per year are as follows (untabulated): 162 (28 percent) are from 2006, 202 (35 percent) are from 2007, and 220 (37 percent) are from 2008.

Of the original 1,443 firm-year observations in Table 1, we lose 78 for which we are unable to obtain information necessary to run the disclosure-choice model, and 815 observations for which carbon emissions data are not available (Table 2). Therefore, we estimate the firm-value model in Equation (1) below with the remaining 550 firm-year observations.[22]

We also collect environmental performance data from KLD STATS, a database that includes annual snapshots of the environmental, social, and governance (ESG) performance of companies rated by KLD Research & Analytics, Inc. Each year, KLD freezes its ratings to reflect the firm status at calendar year-end. KLD STATS provides a binary summary of KLD's ratings based on each firm's environmentally proactive and damaging activities. There are six proactive dimensions, including recycling and clean energy, and seven damaging dimensions, including substantial fines

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19 See https://www.cdproject.net/en-US/Pages/About-Us.aspx. Institutional investors who sign the CDP questionnaire are known as "CDP signatories."

20 See http://www.pwc.com/gx/en/sustainability/publications/carbon-disclosure-project/about.jhtml. We explored other potential sources of carbon emissions data, including the Chicago Climate Exchange (CCX), 10-K reports filed with the SEC, CSR reports, the Pew Center on Global Climate Change, and state and regional reporting initiatives. However, we deemed these sources unsuitable for our study because they do not uniformly report carbon emissions data, or provide only limited data that include very few S&P 500 firms, or report data by facility or state, but not by firm.

21 Firms must respond to this section using the GHG Protocol Corporate Standard (Revised Edition), available at: http://www.ghgprotocol.org/standards/corporate-standard. Firms report their global carbon emissions broken down by Scope 1 (direct emissions from GHG sources owned or controlled by the firm), Scope 2 (indirect emissions caused by the firm's consumption of electricity, heat, cooling or steam brought into its reporting boundary), and Scope 3 (emissions from employee business travel, external distribution/logistics, disposal of the company's products and services, and the company's supply chain). A number of firms in our sample do not provide carbon emissions broken down into scopes.

22 Of the firms that provide carbon emissions information, the two industries with the largest number of observations in our sample are chemical manufacturing and utilities, with 71 firm-years each (untabulated).

TABLE 1

S&P 500 Firms' Responses to CDP Questionnaire and Carbon Emissions Information for Years 2006 to 2008

	Carbon Emissions Available?					
	No	**Percent**	**Yes**	**Percent**	**Total**	**Percent**
Responded to CDP Questionnaire?[a]						
Response publicly available	1[b]	0.07	549	38.04	550	38.11
Response not publicly available	183	12.68	1[c]	0.07	184	12.75
Provided partial information	201	13.93	4[c]	0.28	205	14.21
No/Declined to participate	474	32.85	30[c]	2.08	504	34.93
Total firm-year observations	859	59.53	584	40.47	1,443	100.00
Less: Observations with missing information for disclosure-choice model	44		34		78	
Final sample of firm-year observations	815	59.71	550	40.29	1,365	100.00

[a] The carbon emissions data are collected annually by the CDP on behalf of institutional investors, purchasing organizations, and government bodies. Participation in the CDP questionnaire is voluntary. Therefore, firms may choose to: not respond to the questionnaire/decline to participate; provide partial information (e.g., provide links to information generally available on the firm's website, such as their corporate social responsibility reports) without answering the questionnaire; respond to the questionnaire but not allow the CDP to make the responses publicly available; or respond to the questionnaire and allow CDP to make the responses publicly available.

[b] One firm that responded to the CDP questionnaire and made its responses publicly available did not provide carbon emissions.

[c] These firms declined to participate in the CDP questionnaire, or did not allow the CDP to make their responses publicly available, or provided only partial information in one year; however, we were able to obtain their carbon emissions data from the firms' responses to the CDP questionnaire in a subsequent year.

or penalties paid for violations of environmental regulations.[23] In each case, if KLD identifies a proactive initiative or a damaging action in a particular dimension, then it indicates this with a 1, otherwise the dimension is coded 0.

Empirical Models

Firm-Value Effects of Carbon Emissions

We examine the firm-value effect of carbon emissions using the balance sheet valuation model commonly used in prior literature such as Barth and McNichols (1994) and Campbell et al. (2003). Because managers *choose* to disclose their carbon emissions to the CDP and the public, our sample may be systematically biased, that is, suffer from self-selection bias. We correct for this by jointly estimating the decision to disclose carbon emissions (discussed in the next subsection) and the effect of carbon emissions on firm value (Heckman 1979; Maddala 1983). Equation (1) shows the firm-value model:

$$MKT_t = \beta_0 + \beta_1 TCO2_t + \beta_2 ASSET_t + \beta_3 LIAB_t + \beta_4 OPINC_t + \varepsilon_t, \quad (1)$$

where our proxy for firm value, MKT_t, is the market value of common equity (in millions of dollars), calculated as the number of shares outstanding multiplied by the price per share of the firm's common stock at the end of calendar year *t*. Although the emissions data for the current year

[23] For further details, see the KLD Manual at WRDS: https://wrds-web.wharton.upenn.edu/wrds

TABLE 2
Descriptive Statistics

Panel A: Full Sample and Breakdown of Sample by EPA Group

	Full Sample					*EPA* = 1		*EPA* = 0			
Variable	**Mean**	**Q1**	**Median**	**Q3**	**Std. Dev.**	**Mean**	**Median**	**Mean**	**Median**	**t-stat p-value**	**Wilcoxon p-value**
Firm-Value Model (n = 550)[a]						n = 229		n = 321			
MKT	33,111.41	7,718.98	16,013.08	33,403.01	45,718.14	31,926.01	16,470.81	33,957.06	15,297.94	0.69	0.36
TCO2	11,455.41	262.66	1,068.10	6,849.44	26,712.11	23,741.68	6,467.23	2,690.44	484.67	0.00	0.00
ASSET	59,940.55	9,176.52	19,415.11	40,519.00	148,840.00	35,161.54	22,970.00	77,617.79	17,750.87	0.00	0.31
LIAB	46,803.25	5,054.00	12,330.00	25,288.00	137,389.90	22,326.47	14,437.00	64,264.88	10,342.00	0.00	0.11
OPINC	3,880.59	795.00	1,616.05	3,618.00	6,754.85	3,876.16	1,710.00	3,883.74	1,563.00	0.50	0.22
Disclosure-Choice Model (n = 1,365)[a]						n = 401		n = 964			
CNCRN	0.67	0.00	0.00	1.00	1.15	1.54	1.00	0.31	0.00	0.00	0.00
STRNG	0.53	0.00	0.00	1.00	0.92	0.89	1.00	0.38	0.00	0.00	0.00
PROPDISCL	39.81	25.00	40.00	57.14	24.19	54.89	57.14	33.54	34.78	0.00	0.00
SIZE	9.55	8.57	9.41	10.32	1.37	9.56	9.56	9.55	9.36	0.47	0.09
MF	4.87	0.00	4.00	8.00	4.72	5.12	5.00	4.77	4.00	0.11	0.21
BM	0.49	0.24	0.39	0.62	0.41	0.44	0.37	0.51	0.39	0.01	0.15
LEV	0.40	0.21	0.38	0.57	0.26	0.42	0.42	0.40	0.36	0.03	0.00
II	80.43	71.78	81.28	89.69	14.42	78.26	79.45	81.33	82.00	0.00	0.00
FRNSALE	25.62	0.00	21.23	44.89	25.04	29.04	30.30	24.20	17.23	0.00	0.00

(continued on next page)

TABLE 2 (continued)

Panel B: Breakdown of Sample by Availability of Carbon Emissions Data

	DISC_CDP = 1		*DISC_CDP* = 0			
Variable	**Mean**	**Median**	**Mean**	**Median**	**t-stat p-value**	**Wilcoxon p-value**
Firm-Value Model	n = 550		n = 815[b]			
MKT	33,111.41	16,013.08	14,323.46	8,288.10	0.00	0.00
TCO2	11,455.41	1,068.10	—	—	—	—
ASSET	59,940.55	19,415.11	38,263.42	8,539.00	0.00	0.00
LIAB	46,803.25	12,330.00	32,118.06	5,027.43	0.02	0.00
OPINC	3,880.59	1,616.05	1,921.13	831.00	0.00	0.00
Disclosure-Choice Model						
CNCRN	1.05	0.00	0.41	0.00	0.00	0.00
STRNG	0.96	1.00	0.24	0.00	0.00	0.00
PROPDISCL	54.48	55.26	29.92	30.77	0.00	0.00
SIZE	9.97	9.87	9.27	9.05	0.00	0.00
MF	5.39	5.00	4.53	4.00	0.00	0.37
BM	0.46	0.38	0.51	0.39	0.02	0.01
LEV	0.42	0.40	0.39	0.37	0.03	0.00
II	77.31	77.71	82.53	83.63	0.00	0.00
FRNSALE	32.40	32.07	21.04	13.64	0.00	0.00

[a] We estimate the firm-value model using the 550 firm-year observations for which carbon emissions data are available. We estimate the disclosure-choice model using the 1,365 firm-year observations comprising both disclosing and non-disclosing firms.
[b] For *MKT* we have data for only 812 firm-years in the *DISC_CDP* = 0 group. The three missing firm-year observations are for one firm for which we were not able to obtain both shares outstanding and price data.
For variable definitions see Appendix A.

do not become available to the markets until the middle of the following year, we treat subsequent realizations of the emissions as our best estimate of market expectations.[24]

Our independent variable of interest, $TCO2_t$, denotes carbon emissions in thousands of metric tons. Consistent with our hypothesis of a negative association between carbon emissions and firm value, we expect a negative $TCO2_t$ coefficient. Following prior related research (Barth and McNichols 1994; Campbell et al. 2003), our balance sheet valuation model includes total assets ($ASSET_t$) and liabilities ($LIAB_t$) at the end of the fiscal year, with a positive coefficient expected for $ASSET_t$ and a negative coefficient expected for $LIAB_t$. Consistent with prior research (Barth and McNichols 1994; Campbell et al. 2003) and Barth and Clinch's (2009) finding that unscaled market value of equity estimates generally perform better than scaled market value models, we do not scale MKT_t or $TCO2_t$ in this model. Moreover, the coefficients from an unscaled model are intuitive and economically meaningful (Ziliak and McCloskey 2004).

To control for potential correlated omitted variable bias, we include a proxy for the firm's operating income in year *t*, denoted as $OPINC_t$. Firms with higher operating income are not only valued more highly by the markets, but they are also better able to invest resources for measuring

[24] Although using subsequent realizations gives rise to a look-ahead bias, this is not a concern for our study because we are not proposing trading strategies based on carbon emissions data, but instead are documenting an average firm-value effect. Using end-of-the-year market values is also in line with other literature examining valuation implications of environmental data (Barth and McNichols 1994; Johnston et al. 2008).

and controlling their carbon emissions. It follows that firms with better performance are more likely to have both higher market values and lower emissions. Therefore, we include $OPINC_t$ as an additional control variable in Equation (1) and predict a positive association between $OPINC_t$ and MKT_t. To control for industry-level characteristics, we include industry fixed effects at the two-digit SIC code level in Equation (1). Our financial statement data are from the Compustat database unless otherwise indicated.

Choice to Disclose Carbon Emissions

Firms choose to disclose carbon emissions to the CDP if the perceived benefits of doing so outweigh the perceived costs. Firms are unlikely to disclose their carbon emissions to the CDP if: (1) they have low carbon emissions such that the cost of measuring and collecting this information exceeds the benefits of doing so; (2) the firms have significant carbon emissions but have yet to implement internal measurement systems and processes to collect emissions information; and (3) the firms have a high level of emissions and therefore are reluctant to disclose this "bad news" to investors and other outside stakeholders due to proprietary and other related costs.[25] Because managers' evaluations of the perceived benefits and costs of disclosing are unobservable, we rely on voluntary disclosure theory (Verrecchia 1983; Healy and Palepu 2001) to model managers' disclosure decisions as a function of various firm- and industry-level characteristics.

To control for self-selection, we jointly estimate the decision to disclose carbon emissions and the effect of carbon emissions on firm value (Equation (1)). Equation (2) shows the logit model we use to examine the disclosure choice:

$$\begin{aligned} DISC\_CDP_t = {} & \beta_0 + \beta_1 STRNG_t + \beta_2 CNCRN_t + \beta_3 PROPDISCL_t + \beta_4 SIZE_t + \beta_5 MF_t \\ & + \beta_6 BM_t + \beta_7 LEV_t + \beta_8 II_t + \beta_9 FRNSALE_t + \beta_{10} DISC\_CDP_{t-1} + \beta_{11} EPA_t \\ & + \varepsilon_t, \end{aligned} \tag{2}$$

where $DISC\_CDP_t$ is an indicator variable that is coded as 1 if the firm discloses its year t carbon emissions data to the CDP and allows public disclosure by the CDP, and 0 otherwise. We select the independent variables in model (2) based on economic theory (Akerlof 1970; Milgrom 1981) and on prior research on environmental disclosures (Li et al. 1997; Clarkson, Li, Richardson, and Vasvari 2008).

Environmental Performance Variables

Economic theory predicts that firms with good performance (good type) have incentives to separate themselves from firms with poor performance (bad type) to avoid an adverse selection problem. That is, firms voluntarily reveal credible private information to distinguish themselves from the worst performers (Akerlof 1970; Milgrom 1981). Consistent with this, Clarkson et al. (2008) provide evidence, based on a sample of 191 firms in five high-pollution industries, that firms with better (worse) environmental performance on TRI emissions are more (less) likely to provide voluntary environmental disclosures in environmental and CSR reports.

Economic theory and empirical evidence suggest that firms that are more environmentally proactive, through initiatives such as implementing strong pollution-prevention programs and using renewable energy, have incentives to voluntarily disclose environmental information such as carbon emissions in order to reveal their environmental type, which is not directly observable by investors and other external stakeholders. Thus, we expect a positive coefficient on $STRNG_t$, our measure of

[25] We thank an anonymous reviewer for these insights.

environmentally proactive initiative, measured as the sum of KLD's environmentally proactive performance ratings for a firm in year *t*.

In contrast, economic theory offers competing predictions for environmentally damaging firms. On one hand, firms that are more environmentally damaging are less likely to voluntarily disclose environmental information if outsiders are unable to distinguish whether the non-disclosure is due to poor environmental performance or a desire to not reveal proprietary information (Verrecchia 1983). That is, environmentally damaging firms have incentives not to disclose in order to pool with other non-disclosure firms ascribed by outsiders as the "average" type (Verrecchia 1983; Healy and Palepu 2001). This reasoning argues for a negative coefficient for $CNCRN_t$, our measure of environmentally damaging action, where $CNCRN_t$ is the sum of KLD's environmentally damaging action ratings for a firm in year *t*. On the other hand, if outsiders are able to separate poor performers from good performers, then better performers within the pool of environmentally damaging firms have incentives to disclose. This is because absent such disclosure, uninformed investors and other external stakeholders will form more pessimistic beliefs about management's knowledge of the firms' environmental liabilities based upon publicly available information, thus increasing the probability of disclosure (see Li et al. 1997, Proposition 3d). This discussion predicts a positive $CNCRN_t$ coefficient. Given these two competing theories, we do not predict a sign for $CNCRN_t$.

We examine $STRNG_t$ and $CNCRN_t$ separately because KLD's proactive dimensions are largely distinct from the damaging dimensions. Moreover, prior research (Hughes, Anderson, and Golden 2001; Deegan 2002; Cho et al. 2012) suggests that the likelihood of environmental disclosures by environmentally proactive firms is dissimilar to that of environmentally damaging firms.

Other Independent Variables

$PROPDISCL_t$ measures the proportion of firms in an industry that disclose carbon emissions to the CDP. Consistent with Brown (2011), as more firms in a given industry disclose their carbon emissions, non-disclosers feel greater pressure to disclose them to avoid negative perceptions by outside stakeholders. In addition, we draw on theory showing that as more firms in an industry disclose, outsiders' assessments of the magnitude of non-disclosing firms' environmental liability increase, making it less costly for these firms to report higher liabilities (Li et al. 1997). Furthermore, managers of firms in the same industry face similar cost-benefit trade-offs and may contemporaneously come to a decision to disclose carbon emissions. Finally, based on conversations with sustainability consultants who have direct experience with the CDP questionnaire process, we assume that managers are able to exchange information on such voluntary disclosures with other firms in their industry. Thus, we capture both industry pressure and individually optimal disclosure decisions by including $PROPDISCL_t$, defined as the ratio of firms disclosing their carbon emissions in year *t* to the total firms in the industry in our sample in year *t* (using the two-digit SIC code). We expect a positive $PROPDISCL_t$ coefficient.

Prior research provides evidence of other systematic firm-level characteristics that may increase the likelihood that firms will respond to the CDP questionnaire and disclose their carbon emissions. For example, Stanny and Ely (2008) and Stanny (2013) examine characteristics of firms that respond to the CDP survey and find that size is positively correlated with the probability that firms will respond. Therefore, we include $SIZE_t$, measured using the log of the firm's total assets, and expect a positive sign on this variable. Firms that have a higher propensity to voluntarily disclose information in general may also be more likely to disclose their carbon emissions. Following Clarkson, Fang, Li, and Richardson (2010), we include the number of management forecasts issued by the firm during the year, denoted as MF_t, to control for the firm's general disclosure propensity. We expect a positive MF_t coefficient.

We control for firm growth by including the book-to-market ratio (BM_t) of the firm, but we do not predict a sign for BM_t. Prior research finds that firms with higher disclosure quality have lower cost of debt (Sengupta 1998). Consistent with higher-leverage firms providing higher-quality disclosures, we expect the coefficient on firm leverage, LEV_t, to be positive. Since the CDP is a consortium of large institutional investors, firms with higher institutional holdings may be more likely to disclose their carbon emissions, owing to investors' calls for more transparent disclosures about socially responsible activities (Plumlee, Brown, Hayes, and Marshall 2010). Alternatively, firms with fewer institutional investors may be more likely to respond to the CDP questionnaire to attract more institutional investors. Thus, we also control for the proportion of total shares outstanding held by institutional investors, II_t, from the Thomson Reuters 13-F database, but do not predict its sign.

Product market interactions affect firms' voluntary disclosures (Khanna, Palepu, and Srinivasan 2004) and European Union firms with higher proportions of international sales are more likely to disclose their carbon emissions (Stanny and Ely 2008). Therefore, to control for international product market interactions, we include in our logit model annual foreign sales as a proportion of total sales ($FRNSALE_t$) from the Worldscope database. S&P 500 firms that generate more earnings from outside the U.S. are more likely to respond to the CDP questionnaire, so we expect a positive $FRNSALE_t$ coefficient.

Consistent with Stanny (2013), we include an indicator variable, EPA_t, which is coded as 1 for firms that will be subject to the EPA's GHG mandatory reporting rule, and 0 otherwise.[26] Many of the firms in the $EPA = 1$ group also have industry-specific reporting requirements regarding their GHG emissions.[27] Therefore, we expect a positive coefficient for EPA_t. We include a lagged emissions indicator, $DISC\_CDP_{t-1}$, as an additional explanatory variable in our logit model. We expect a positive coefficient on $DISC\_CDP_{t-1}$, consistent with Stanny's (2013) finding that firms that responded to the CDP questionnaire in the previous year are eight times more likely to respond in the current year; that is, these disclosure decisions are "sticky." Finally, to control for industry-level characteristics, we include industry fixed effects at the two-digit SIC code level in Equation (1).

Firm-Value Effects of Decision to Disclose Carbon Emissions

As argued earlier, managers weigh the perceived costs and benefits of disclosing carbon emissions and choose to disclose only if the benefits of doing so outweigh the costs. Prior research on voluntary disclosures finds that *ceteris paribus*, firms that choose higher levels of voluntary disclosures have higher market values (Healy and Palepu 2001). Therefore, we also examine the firm-value effects of the decision to voluntarily disclose carbon emissions.

Using propensity score matching (Rosenbaum 2005), we compare the firm values for the firms that choose to disclose their carbon emissions with a matched sample of firms that choose to not disclose this information. To calculate the propensity scores we run a logit model using all the variables in Equations (1) and (2) above, except $TCO2_t$ and $DISC\_CDP_{t-1}$. We exclude $TCO2_t$ because it is available only for disclosing firms and $DISC\_CDP_{t-1}$ because it is the dependent variable in the previous year, and therefore not a "proper" covariate (Stuart and Rubin 2008). We match each disclosing firm to the closest non-disclosing firm(s) using two different matching algorithms, nearest-neighbor matching and caliper matching, and test for the difference in means and medians of firm value between the matched firms.

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[26] Consistent with the EPA, we use the North American Industry Classification System (NAICS) to classify firms as $EPA = 1$ and $EPA = 0$.

[27] For instance, firms in the Oil and Gas industry are required to calculate their GHG emissions using techniques provided by the Compendium of GHG Emission Estimation Methodologies for the Oil and Gas Industry and the Petroleum Industry Guidelines for Reporting GHG Emissions.

There is a trade-off between: (1) including in the model all observable characteristics that distinguish the disclosing and non-disclosing firms; and (2) the ability to find a non-disclosing firm that matches each disclosing firm on all the included characteristics (Wooldridge 2012). Therefore, to increase the probability of finding a match, we also estimate the model after dropping some of the variables that are not significant in the original model. Propensity score matching alone is often sufficient to yield consistent or even efficient estimates. However, because it may not completely eliminate all systematic differences between the disclosing and non-disclosing firm means, we augment propensity score matching by using doubly robust regression (Imbens and Wooldridge 2007). Also, doubly robust regression allows us to obtain robust standard errors (Wooldridge 2012). More specifically, after matching our disclosing ($DISC\_CDP_t = 1$) and non-disclosing firms ($DISC\_CDP_t = 0$) using the propensity scores calculated with the logit model, we estimate Equation (1) for only the matched sample, replacing $TCO2_t$ with $DISC\_CDP_t$ and using the propensity scores as weights.

IV. RESULTS

Descriptive Statistics

Panel A of Table 2 shows summary statistics for our full sample of S&P 500 firms. Panel A also shows the sample breakdown by EPA group, those firms required by the EPA to disclose their carbon emissions for 2010 and thereafter ($EPA = 1$), and firms exempt from the EPA's reporting rule ($EPA = 0$). Panel B of Table 2 provides summary statistics for our sample firms broken down into $DISC\_CDP = 1$, those that disclosed their carbon emissions publicly in the CDP questionnaire, and those that did not, $DISC\_CDP = 0$. We winsorize all the continuous variables at the 1 percent level on both tails of the distribution.

As shown in Table 2, Panel A, the distributions of both *MKT* and *TCO2* are significantly skewed. Therefore, we report parametric tests for the means and nonparametric tests for the medians. Panel A confirms that our sample consists of extremely large firms, with mean (median) market value (*MKT*) of $33.11 ($16.01) billion. The mean of *TCO2* is considerably larger than the median *TCO2*, indicating the presence of some large carbon emitters. Carbon emissions are significantly higher for the $EPA = 1$ group. Also, there is no significant difference in the market value of firms in the $EPA = 1$ and $EPA = 0$ groups.

Panel A of Table 2 also shows that the mean book values of total assets (*ASSET*) and total liabilities (*LIAB*) are significantly higher for the $EPA = 0$ group than for the $EPA = 1$ group. However, the respective median book values are not significantly different between the $EPA = 1$ and $EPA = 0$ groups at conventional levels. Taken together, the aforementioned firm characteristics indicate that the difference in carbon emissions between the two groups is not an artifact of firm size. Further, Panel B of Table 2 shows that the $DISC\_CDP = 1$ firms are bigger than the $DISC\_CDP = 0$ firms for *MKT*, *ASSET*, and *LIAB*, with significantly larger mean and median for the former group ($p = 0.00$).

Panel A of Table 2 shows that, consistent with institutional investors owning a significant portion of S&P 500 firms, both the mean and median institutional investors (*II*) ownership for our sample firms is about 80 percent. Panels A and B show that both the percentage of foreign sales, *FRNSALE*, and the percentage of firms disclosing emissions relative to the total firms in the industry, *PROPDISCL*, are higher for the $EPA = 1$ and $DISC\_CDP = 1$ groups. Interestingly, the mean and median levels of *II* are higher for firms in the $EPA = 0$ and $DISC\_CDP = 0$ groups.

Table 3 reports Spearman rank (Pearson) correlation coefficients above (below) the diagonal. Because a number of the variables used in our analyses are indicator variables and there is

TABLE 3
Correlation Coefficients

	MKT	*TCO2*	*ASSET*	*LIAB*	*OPINC*	*CNCRN*	*STRNG*	*PROP-DISC*	*SIZE*	*MF*	*BM*	*LEV*	*II*	*FRN-SALE*
MKT		**0.150**	**0.450**	**0.381**	**0.753**	**0.197**	**0.224**	**0.074**	**0.560**	0.005	**−0.162**	**−0.071**	**−0.324**	**0.176**
TCO2	**0.267**		0.045	0.008	**0.296**	**0.552**	−0.004	**0.213**	**0.227**	−0.023	**0.113**	0.063	**−0.248**	**−0.123**
ASSET	**0.642**	**0.403**		**0.995**	**0.728**	0.000	−0.005	*−0.082*	**0.687**	**−0.142**	**0.137**	**0.296**	**−0.218**	**−0.100**
LIAB	**0.539**	**0.426**	**0.965**		**0.680**	−0.029	−0.022	**−0.094**	**0.654**	**−0.144**	**0.135**	**0.318**	**−0.198**	**−0.111**
OPINC	**0.818**	**0.366**	**0.748**	**0.693**		**0.204**	**0.122**	0.002	**0.623**	*−0.064*	−0.030	**0.128**	**−0.242**	*0.051*
CNCRN	**0.172**	**0.684**	**0.234**	**0.242**	**0.265**		**0.357**	**0.375**	**0.212**	0.002	0.010	**0.074**	**−0.201**	**0.091**
STRNG	**0.193**	**0.230**	**0.142**	**0.130**	**0.195**	**0.391**		**0.281**	**0.126**	**0.112**	**−0.114**	−0.008	**−0.124**	**0.365**
PROPDISCL	**0.102**	**0.474**	**0.146**	**0.155**	**0.172**	**0.401**	**0.346**		**0.095**	**0.098**	−0.025	**0.099**	**−0.171**	**0.202**
SIZE	**0.642**	**0.403**	**1.000**	**0.965**	**0.748**	**0.234**	**0.142**	**0.146**		**−0.109**	**0.223**	**0.314**	**−0.373**	**−0.172**
MF	0.035	−0.025	**−0.100**	**−0.093**	0.035	0.035	**0.119**	**0.113**	**−0.100**		**−0.159**	*−0.049*	0.039	0.002
BM	**−0.282**	*0.103*	**0.297**	**0.263**	*−0.058*	*0.062*	**−0.076**	0.028	**0.297**	**−0.145**		*0.046*	0.027	**−0.249**
LEV	**−0.108**	**0.256**	**0.276**	**0.443**	**0.089**	**0.118**	−0.001	**0.116**	**0.276**	−0.029	*0.046*		*−0.054*	**−0.226**
II	**−0.345**	**−0.277**	**−0.385**	**−0.361**	**−0.349**	**−0.217**	**−0.133**	**−0.180**	**−0.385**	0.044	0.007	*−0.066*		0.029
FRNSALE	**0.121**	**−0.178**	**−0.177**	**−0.226**	0.003	**0.115**	**0.355**	**0.204**	**−0.177**	0.038	**−0.288**	**−0.255**	0.033	

Coefficients in italic are significant at $p < 0.10$.
Coefficients in bold are significant at $p < 0.01$.
Coefficients in plain text are not significant ($p > 0.10$).
$n = 550$ for firm-value model and $n = 1{,}365$ for disclosure-choice model. See note a in Table 2.
Spearman rank (Pearson) correlation coefficients are below (above) the diagonal.
For variable definitions see Appendix A.

considerable skewness in the data, as described above, we discuss the Spearman rank correlation coefficients here. *TCO2* and *MKT* are positively correlated, which may be due to firm size; that is, larger firms with high *MKT* also have higher carbon emissions. The correlation between emissions (*TCO2*) and leverage (*LEV*) is positive and significant (0.256; $p < 0.01$), indicating that firms with higher emissions have more assets-in-place or are more capital-intensive (i.e., investments already made by the firm), compared to firms with lower emissions, which may have more growth opportunities (i.e., more real options for future investments) (Myers 1977). The correlation between *TCO2* and percentage of shares held by institutional investors (*II*) is −0.277 ($p < 0.01$), consistent with high-carbon-emitting firms having lower institutional investor holdings. Finally, the correlation between *TCO2* and the percentage of foreign sales (*FRNSALE*) is −0.178 ($p < 0.01$), indicating that higher- (lower-) carbon-emitting firms have a lower (higher) percentage of foreign sales.

Firm-Value Effects of Carbon Emissions

To correct for self-selection, we estimate the Heckman model (Heckman 1979; Maddala 1983) using the Full Information Maximum Likelihood (FIML) approach (Tucker 2010); that is, we estimate the firm-value model (Equation (1)) jointly with the disclosure-choice model (Equation (2)). Correcting for self-selection bias allows us to make inferences about the average effect of carbon emissions on firm value for all the firms in the sample, not just for the firms that disclose their emissions. Table 4 presents our results. We report t-statistics based on robust standard errors.

The coefficient on $TCO2_t$ in Equation (1) for the full sample ($\beta_1 = -0.212$; $p < 0.01$) is negative and significant, consistent with H1. This result has economic significance because, on average, for every additional thousand metric tons of carbon emissions, firm value decreases by $212,000. This translates to a $1.4 billion reduction in firm-value moving from a firm in the first quartile of carbon emissions to one in the third quartile of emissions. The signs of coefficients on the other variables in the model are as expected.

To examine whether the markets value carbon emissions differently for the $EPA = 1$ and $EPA = 0$ groups, we estimate Equation (1) separately for each subgroup. Table 4 shows that the coefficient on $TCO2_t$ for the $EPA = 1$ group is negative and significant ($\beta_1 = -0.182$; $p < 0.01$). Similarly, the coefficient on $TCO2_t$ for the $EPA = 0$ group is negative ($\beta_1 = -0.176$); however, it is not significant at conventional levels ($p = 0.11$).

Although FIML is more efficient, it may be less robust than Limited Information Maximum Likelihood (LIML), the two-step estimator (Wooldridge 2002, 566). Therefore, we also run the analyses above using LIML (untabulated). Specifically, we calculate the Inverse Mills Ratio (IMR) from the disclosure-choice model, and then include it in the firm-value model.[28] We include industry-level fixed effects in the firm-value model. Our results are unchanged except for the $EPA = 0$ group, where the coefficient on $TCO2_t$ is now significant at $p < 0.01$.

[28] Lennox, Francis, and Wang (2012) point out the importance of imposing "exclusion restrictions" when using the Heckman procedure. This is because absence of exclusion restrictions in the selection model (Equation (2)) can lead to biased coefficients that may be due to multicollinearity in the firm-value model (Equation (1)). The exclusion restriction requires at least one variable in the selection model that is conceptually excluded from the firm-value model. To satisfy the exclusion restriction, we include in our selection model a number of variables, such as *PROPDISCL*, *FRNSALE*, and *EPA*, which are related to the firm's decision to disclose carbon emissions but do not directly affect firm value. Thus, we exclude these variables from the firm-value model. Lennox et al. (2012) point out the importance of testing for multicollinearity when using the Heckman procedure. We find that the variance inflation factor (VIF) for the IMR is less than 2 for the full sample and for the $EPA = 1$ and $EPA = 0$ subgroups, thus indicating that multicollinearity is not an issue.

TABLE 4

Firm-Value Effects of Carbon Emissions

Variable	Pred. Sign	Full Sample Coeff.	Full Sample Z-stat	$EPA = 1$ Coeff.	$EPA = 1$ Z-stat	$EPA = 0$ Coeff.	$EPA = 0$ Z-stat
$TCO2_t$	H1: −	−0.212***	−3.72	−0.182***	−3.89	−0.176	−1.24
$ASSET_t$	+	1.129***	8.82	1.597***	5.95	1.228***	7.09
$LIAB_t$	−	−1.186***	−9.18	−1.624***	−5.97	−1.310***	−7.57
$OPINC_t$	+	4.421***	10.49	1.907**	2.06	5.200***	8.08
Disclosure-Choice Model ($DISC\_CDP_t$)							
$CNCRN_t$	?	−0.034	−0.51	0.077	1.00	−0.279**	−2.14
$STRNG_t$	+	0.305***	4.29	0.283***	2.40	0.293***	2.65
$PROPDISCL_t$	+	0.025***	5.41	0.017**	2.08	0.030***	5.59
$SIZE_t$	+	0.394***	6.03	0.658***	5.46	0.331***	5.58
MF_t	+	0.014	1.26	0.005	0.30	0.016	1.14
BM_t	?	−0.619***	−4.23	−1.481***	−5.79	−0.446***	−2.95
LEV_t	+	−0.527§§§	−2.38	−0.840§§	−2.34	−0.444§§	−1.74
II_t	?	−0.001	−0.27	−0.008	−1.34	0.000	0.06
$FRNSALE_t$	+	0.009***	3.40	0.006	1.19	0.008**	2.26
$DISC\_CDP_{t-1}$	+	1.286***	7.30	0.679***	3.24	1.607***	9.45
EPA_t	+	0.268	1.07				
Likelihood Ratio χ^2		2.88*		22.31***		0.14	
n		1,365		401		964	
Uncensored		550		229		321	

*, **, *** Denote significance at $p < 0.10$, < 0.05, and < 0.01, respectively, one-tailed where a directional prediction is made.
§§, §§§ Denote significance at $p < 0.05$ and < 0.01, respectively, if the coefficient is significant in the opposite direction where a directional prediction is made. Otherwise, p-values are two-tailed.
For parsimony, coefficients on industry dummies are not reported.
Using the Full Information Maximum Likelihood (FIML) method, we estimate the Heckman (1979) model to correct for selection bias; that is, we estimate the firm-value model jointly with the disclosure choice model. We estimate the model on the full sample and separately for $EPA = 1$ and $EPA = 0$ firms. We include industry fixed effects at the two-digit SIC code level in both models. We report Z-statistics based on Huber-White robust standard errors:

$$MKT_t = \beta_0 + \beta_1 TCO2_t + \beta_2 ASSET_t + \beta_3 LIAB_t + \beta_4 OPINC_t + \varepsilon_t. \quad (1)$$

Disclosure-Choice Model:

$$DISC\_CDP_t = \beta_0 + \beta_1 CNCRN_t + \beta_2 STRNG_t + \beta_3 PROPDISCL_t + \beta_4 SIZE_t + \beta_5 MF_t + \beta_6 BM_t + \beta_7 LEV_t + \beta_8 II_t + \beta_9 FRNSALE_t + \beta_{10} DISC\_CDP_{t-1} + \beta_{11} EPA_t + \varepsilon_t. \quad (2)$$

$DISC\_CDP_t$ is an indicator variable equal to 1 if the firm publicly discloses carbon emissions, and 0 otherwise. The likelihood ratio χ^2 statistic is a test of the null hypothesis that there is no self-selection. The p-value for the goodness-of-fit test in this table is 0.00.
For variable definitions see Appendix A.

Also, Table 4 shows that the likelihood ratio Chi-square statistics that test the null hypothesis of no self-selection are significant for the full sample and for the $EPA = 1$ group, thus highlighting the importance of correcting for self-selection bias when examining the relationship between carbon emissions and firm value. Our results for the full sample as well as for the $EPA = 1$ group are both economically large and statistically significant. Overall, our results support our prediction that firm value is negatively associated with carbon emissions.

Self-Selection: Choice to Voluntarily Disclose Carbon Emissions

Table 4 also presents the results of estimating the disclosure-choice model in Equation (2). For the full sample and for firms in both the $EPA = 1$ and $EPA = 0$ groups, the coefficient on $STRNG_t$ is positive and significant ($p < 0.01$). These results indicate that in both groups, the higher the firms' scores on environmentally proactive initiatives, the more likely they are to disclose their carbon emissions. The coefficient on $CNCRN_t$ is not significantly different from zero for the full sample and for firms in the $EPA = 1$ group. In contrast, for firms in the $EPA = 0$ group, the coefficient on $CNCRN_t$ is negative and significant ($p < 0.05$), thus indicating that the higher the firms' scores on environmentally damaging actions, the less likely they are to disclose their carbon emissions.

The coefficient on $PROPDISCL_t$ is positive and significant for the full sample ($p < 0.01$) and for firms in both the $EPA = 1$ and $EPA = 0$ groups ($p < 0.05$ and $p < 0.01$, respectively), consistent with the probability of disclosure increasing as more firms in the industry disclose. The coefficient on $SIZE_t$ is positive and highly significant ($p < 0.01$), consistent with prior voluntary disclosure literature. Contrary to our expectations, firms with higher leverage, LEV_t, are less likely to disclose their carbon emissions. The coefficient on $FRNSALE_t$ is positive and significant for the full sample ($p < 0.01$) and for firms in the $EPA = 0$ group ($p < 0.05$). This is consistent with Stanny and Ely (2008), who find that the proportion of firms' foreign sales to total sales is positively associated with the firms' choice to respond to the CDP questionnaire. Finally, consistent with expectations, we find that firms that disclosed their carbon emissions in the prior year are significantly more likely to disclose their emissions in the current year ($p < 0.01$), indicating that the disclosure decision is sticky. The coefficients on the other variables in the model are either as predicted or not significantly different from 0.

Firm-Value Effects of Decision to Disclose Carbon Emissions

Our results indicate that the markets impose a penalty for firms' carbon emissions. This raises the question: "Why do firms voluntarily disclose their carbon emissions, given that the markets treat them as a cost or liability?" As discussed in Section II, it is not clear whether the markets will reward or penalize voluntary disclosers of carbon emissions. We address this question by using propensity score matching and doubly robust regression to examine the firm-value effects of the act of voluntarily disclosing carbon emissions, represented by $DISC\_CDP_t$.

Table 5, Panel A presents two logit models for the disclosure choice: (i) the full model with all the covariates from Equations (1) and (2); and (ii) a reduced model including only selected covariates. We use two matching algorithms: (i) nearest neighbor matching, and (ii) caliper matching with a distance of 0.01. To assess the quality of matching, we present the covariate balance for each model after matching. In the full model, we find that only some of the covariates are significant in explaining the firms' choice to disclose. The differences in means of the covariates for the matched firms indicate that the matched firms differ on only LEV_t and $OPINC_t$ ($p < 0.05$). Covariate balances for caliper matching are similar to the balances for nearest neighbor matching. To increase the number of firms that we are able to match, we next drop covariates that are both (i) statistically insignificant in the logit model and (ii) insignificantly different between the disclosing and non-disclosing firms after matching. In this reduced model, the means of the covariates are now different for MF_t and LEV_t ($p < 0.10$) and for $FRNSALE_t$ and EPA_t ($p < 0.05$) using nearest neighbor matching. None of the covariates are significantly different from 0 using caliper matching.

Table 5, Panel B presents the differences in the mean firm values for disclosing and non-disclosing firms. Using nearest neighbor matching, the difference in the mean firm values of the propensity score matched firms is approximately \$13.61 billion for the full model, and approximately \$11.42 billion for the reduced model, both significant at $p < 0.01$. Using caliper

TABLE 5

Firm-Value Effects of Decision to Disclose Carbon Emissions: Propensity-Score Matching

Panel A: Logit Model for Propensity Score Matching[a]

	Full Model					Reduced Model				
$DISC\_CDP_t$	Estimates		Covariate Bal (Near Neighbor)			Estimates		Covariate Bal (Near Neighbor)		
Variable	Coeff.	Z-stat	Discl.	Non-Discl.	Z-stat	Coeff.	Z-stat	Discl.	Non-Discl.	Z-stat
$CNCRN_t$	−0.036	−0.35	1.03	1.01	0.23			1.036	1.05	−0.13
$STRNG_t$	0.795***	6.84	0.97	0.88	1.40	0.833***	7.48	0.979	0.94	0.64
$PROPDISCL_t$	0.061***	7.36	53.46	54.16	−0.62	0.060***	7.40	52.867	52.58	0.25
$SIZE_t$	0.547***	4.51	9.97	9.97	0.05	0.535***	6.16	10.030	10.03	0.03
MF_t	0.034*	1.93	5.45	5.93	−1.38	0.030*	1.75	5.352	5.95	−1.71*
BM_t	0.030	0.71	0.47	0.51	−1.57			0.379	0.42	−0.32
LEV_t	−0.243	−0.69	0.42	0.46	−2.25**	−0.209	−0.81	0.430	0.47	−1.77*
II_t	−0.003	−0.44	77.21	78.17	−1.15			77.190	78.37	−1.42
$FRNSALE_t$	0.021***	4.77	32.15	33.73	−0.94	0.021***	4.96	32.277	36.05	−2.31**
EPA_t	0.729*	1.87	0.43	0.38	1.55	0.927**	2.43	0.420	0.35	2.34**
$ASSET_t$	0.000	0.58	58,418	48,523	1.340			68,491	79,315	−1.010
$LIAB_t$	0.000	−0.65	46,112	38,952	1.020			56,218	69,450	−1.280
$OPINC_t$	0.000	0.86	3,841	2,685	3.710***	0.000**	2.55	4,208	4,073	0.310
n	1,234					1,286				
Treated	538					559				
Pseudo R^2	0.299					0.303				

*, **, *** Denote significance at $p < 0.10$, < 0.05, and < 0.01, respectively.

[a] We match firms that disclose their carbon emissions, $DISC\_CDP_t = 1$ with firms that do not disclose their carbon emissions, $DISC\_CDP_t = 0$, using the following logit model that includes all the variables in Equations (1) and (2). We use two matching algorithms, nearest neighbor matching and caliper matching with a distance of 0.01. We include industry fixed effects at the two-digit SIC code level:

$$DISC\_CDP_t = \beta_0 + \beta_1 CNCRN_t + \beta_2 STRNG_t + \beta_3 PROPDISCL_t + \beta_4 SIZE_t + \beta_5 MF_t + \beta_6 BM_t + \beta_7 LEV_t + \beta_8 II_t + \beta_9 FRNSALE_t + \beta_{10} EPA_t + \beta_{11} ASSET_t + \beta_{12} LIAB_t + \beta_{13} OPINC_t + \varepsilon_t.$$

To increase the overlap between the disclosing and non-disclosing firms (i.e., the common support area), we also estimate a reduced model excluding covariates that were not significant in the logit regression, and covariates whose means did not differ significantly after matching. We report covariate balance means and Z-stats to test how equal (balanced) the disclosing and non-disclosing firms are for each covariate after matching only for nearest neighbor matching. Covariate balances are similar using caliper matching in the full model. In the reduced model there are no covariates that are significantly different between the disclosing and non-disclosing firms using caliper matching.

(continued on next page)

TABLE 5 (continued)

Panel B: Difference in Mean Firm Values of Propensity Score-Matched Firms[b]

		Full Model				Reduced Model			
		Disclosers	**Non-Discl.**	**Diff.**	**Z-stat**	**Disclosers**	**Non-Discl.**	**Diff.**	**Z-stat**
Nearest Neighbor	Mean firm value	33,440.7	19,829.2	13,611.5***	4.50	34,077.0	22,661.5	11,415.5***	3.04
	n	538	696			559	727		
Caliper (0.01)	Mean firm value	29,615.2	19,718.8	9,896.4***	3.64	30,309.1	22,836.1	7,473.0**	2.26
	n	496	696			519	727		

*, **, *** Denote significance at $p < 0.10$, < 0.05, and < 0.01, respectively.

[b] Using the propensity scores from the logit regressions in Panel A, we match our disclosing firms ($DISC\_CDP_t = 1$) with the non-disclosing firms ($DISC\_CDP_t = 0$). This panel provides the difference in means of the firm value for our matched firms, i.e., the average effect on the disclosing firms, using both nearest neighbor and caliper matching algorithms.

Panel C: Doubly Robust Regression Estimates of Mean and Median Firm Value[c]

		Mean Firm Value[d]				Median Firm Value[e]			
		Full Model		Reduced Model		Full Model		Reduced Model	
		Coefficient	**Z-stat**	**Coefficient**	**Z-stat**	**Coefficient**	**Z-stat**	**Coefficient**	**Z-stat**
Nearest Neighbor	$DISC\_CDP_t$	6,352.7***	2.75	5,712.7**	2.55	2,869.4***	9.19	2,268.5***	8.34
	n	1,234		1,286		1,076		1,118	
Caliper (0.01)	$DISC\_CDP_t$	5,160.8***	3.53	5,062.5***	2.74	2,265.0***	4.79	2,097.8***	8.76
	n	992		1,038		992		1,038	

*, **, *** Denote significance at $p < 0.10$, < 0.05, and < 0.01, respectively.

[c] After matching our disclosing and non-disclosing firms using the propensity scores calculated in Panel A for the two models, we examine the difference in the mean and median firm values between the disclosing and non-disclosing firms using the following regression:

$$MKT_t = \beta_0 + \beta_1 DISC\_CDP_t + \beta_2 ASSET_t + \beta_3 LIAB_t + \beta_4 OPINC_t + \varepsilon_t.$$

The regressions are run using propensity scores from the logit model in Panel A.

[d] We include industry fixed effects in the regression model and report Z-statistics based on robust standard errors.

[e] We do not include industry fixed effects in the median regressions because the model does not converge with industry fixed effects.

For variable definitions see Appendix A.

matching, the difference in the mean firm values is smaller: \$9.90 billion for the full model ($p < 0.01$) and \$7.47 ($p < 0.05$) billion for the reduced model.

To eliminate any remaining bias after propensity score matching, we run doubly robust regressions of firm value on the firms' decision to disclose carbon emissions, $DISC\_CDP_t$. Results for the full model in Table 5, Panel C, show that the mean firm value of disclosing firms is significantly higher than that of non-disclosing firms by approximately \$6.35 billion (\$5.16 billion) for nearest neighbor (caliper) matching ($p < 0.01$). Similarly, results for the reduced model show that, on average, the mean firm value of disclosing firms is higher than non-disclosing firms by approximately \$5.71 (\$5.06) billion for nearest neighbor (caliper) matching. These differences are significant at $p < 0.01$. The difference in mean firm value is smaller using doubly robust regression as compared to the results from propensity score matching only. This suggests that there was some residual bias, which we were able to remove using doubly robust regression.

We also estimate the effects of disclosing carbon emissions on median firm value, matching firms using propensity scores and then estimating quantile regressions using weights from the matching procedure (Table 5, Panel C). We do not include industry fixed effects in the quantile regression because our model does not converge, but we do include industry fixed effects in the matching procedure. Our results using nearest neighbor (caliper) matching for the reduced model show that the median firm value of disclosing firms is about \$2.27 (\$2.10) billion higher than that of non-disclosing firms. These differences are significant at $p < 0.01$. The differences in median firm values between disclosing and non-disclosing firms are slightly higher using the full model ($p < 0.01$).[29]

Sensitivity Analyses

We conduct several sensitivity analyses to assess the robustness of our main results. First, we examine the relationship between changes in firm value, (ΔMKT_t) and changes in carbon emissions, $\Delta TCO2_t$ (Table 6). Consistent with our main results, we find that increases in carbon emissions are associated with decreases in firm value. In particular, the coefficient on $\Delta TCO2_t$ is negative and significant for the full sample ($p < 0.01$), for the $EPA = 1$ group ($p < 0.05$), and for the $EPA = 0$ group ($p < 0.10$).

Second, we scale both the dependent and independent variables in Equation (1) by the number of common shares outstanding. Our inferences (untabulated) regarding the negative association between $TCO2_t$ and MKT_t are unchanged for the full sample and for the $EPA = 1$ group. However, for the $EPA = 0$ group, the negative coefficient on $TCO2_t$ is now significant ($p < 0.01$). We also scale all of the variables by sales and our results are unchanged.

Third, we estimate the firm-value effects of carbon emissions using the Ohlson (1995) model, which provides a theoretical framework for the interpretation of the $TCO2$ coefficient in terms of the valuation implications of the firms' carbon emissions. Specifically, we estimate the following valuation model jointly with the disclosure-choice model specified in Equation (2):

$$MKT_t = \beta_0 + \beta_1 TCO2_t + \beta_2 CEQ_t + \beta_3 IBEI_t + \varepsilon_t, \tag{3}$$

where CEQ_t is the value of common equity of the firm and $IBEI_t$ is income before extraordinary items. We scale all the variables in the model by common shares outstanding. Our results (untabulated) show that the coefficient on $TCO2_t$ is negative and significant ($p < 0.05$ for the full sample and for the $EPA = 1$ group, and $p < 0.01$ for the $EPA = 0$ group). Other coefficients are also in the expected direction and significant ($p < 0.05$).

Fourth, we include firms with December fiscal year-end only. Because the carbon emissions data and market-value data are for the calendar year-end but the accounting data are for fiscal year-end, using firms with December fiscal year-end only better aligns the accounting data with carbon emissions and market-value data. Our results (untabulated) are consistent with the main results reported in Table 4. In other untabulated analyses, we also include return on assets as an additional control variable in the logit model. This variable is significant for the full sample and

[29] Our results do not imply that all firms are penalized equally for non-disclosure. Instead, the difference in market value that we document in Table 5 is the difference in the mean and median (Panel C) firm value for disclosing versus non-disclosing firms, conditional on various firm-level characteristics, including carbon emissions.

TABLE 6

Firm-Value Effects of Carbon Emissions Changes Model

ΔMKT_t		Full Sample		$EPA = 1$		$EPA = 0$	
Variable	**Pred. Sign**	**Coeff.**	**t-stat**	**Coeff.**	**t-stat**	**Coeff.**	**t-stat**
$\Delta TCO2$	H1: −	−0.045***	−2.45	−0.063**	−2.17	−0.020*	−1.28
$\Delta ASSET$	+	1.207***	4.90	2.158***	2.60	1.005***	4.52
$\Delta LIAB$	−	−0.040	−0.30	−0.942***	−2.58	0.074	0.76
$\Delta OPINC$	+	0.097**	1.73	0.028	0.21	0.121**	1.67
n		313		136		177	
R^2		0.2		0.2		0.33	

*, **, *** Denote significance at $p < 0.10$, < 0.05, and < 0.01, respectively, one-tailed where a directional prediction is made. Otherwise, p-values are two-tailed.

We estimate the following model to examine the percentage change in firm value as a function of the percentage change in carbon emission levels, controlling for other factors that are associated with firm value. We include firm fixed effects in all the estimations. We estimate the model on the full sample and separately for $EPA = 1$ and $EPA = 0$ firms. We report t-statistics based on Huber-White robust standard errors:

$$\Delta MKT_t = \beta_0 + \beta_1 \Delta TCO2_t + \beta_2 \Delta ASSET_t + \beta_3 \Delta LIAB_t + \beta_4 \Delta OPINC_t + \varepsilon_t.$$

Variable Definitions:
$\Delta MKT_t = [(MKT_t + DIV_t) - (MKT_{t-1} + DIV_{t-1})]/(MKT_{t-1} + DIV_{t-1})$;
DIV_t = dividend for year t;
$\Delta TCO2_t = (TCO2_t - TCO2_{t-1})/TCO2_{t-1}$;
$\Delta ASSET_t = (ASSET_t - ASSET_{t-1})/ASSET_{t-1}$;
$\Delta LIAB_t = (LIAB_t - LIAB_{t-1})/LIAB_{t-1}$; and
$\Delta OPINC_t = (OPINC_t - OPINC_{t-1})/OPINC_{t-1}$.
The other variables are as defined in Appendix A.

for the $EPA = 0$ group ($p < 0.05$), and not significant for the $EPA = 1$ group. Our main results remain unchanged.

Finally, because our firm-value model controls only for assets and liabilities that are recognized on the firms' balance sheets, we conduct sensitivity analyses (untabulated) to rule out the alternative explanation that the negative coefficient on $TCO2_t$ in Table 4 is proxying for other unbooked liabilities. We first add TRI emissions, TRI_t, in Equation (1) as a proxy for other unbooked environmental liabilities, following Clarkson et al. (2010).[30] Because TRI data are unavailable for some firms, we lose over 60 percent of the observations from the $EPA = 0$ group (we lose over 43 percent of the observations from the full sample). The coefficient on TRI_t is negative and significant for the full sample and for the $EPA = 1$ group, but it is not significant for the $EPA = 0$ group. We next include the firms' credit ratings as a proxy for all other relevant information, including all unbooked liabilities. The coefficient on credit ratings is positive and significant ($p < 0.01$), consistent with the intuition that firms with higher credit ratings have higher firm values. For both these analyses, our results for $TCO2_t$ remain unchanged. Taken together, the results of our

[30] Specifically, we measure TRI_t as TRI emissions scaled by sales. Consistent with Clarkson et al. (2011), we then assign the scaled TRI emissions into deciles within each industry (two-digit SIC code).

sensitivity analyses are generally consistent with our main results and support our prediction that firm value is negatively associated with carbon emissions.[31]

V. CONCLUSION AND DISCUSSION

Using carbon emissions data for 2006 to 2008 that S&P 500 firms disclosed voluntarily, we find that the capital markets integrate both carbon emissions and the *act* of voluntary disclosure of this information into their firm valuations. The markets penalize all firms for their carbon emissions; firms that do not disclose their carbon emissions face a further penalty for non-disclosure. To our knowledge, this is the first study to provide empirical evidence on the firm-value effects of *both* the choice to voluntarily disclose carbon emissions and the magnitude of carbon emissions.

We predict and find a negative association between carbon emissions and firm value. Correcting for self-selection bias associated with managers' decisions to disclose carbon emissions, we find that for every additional thousand metric tons of carbon emissions, firm value decreases, on average, by $212,000. Our finding of a negative association between carbon emissions and firm value begs the question: "If the capital markets penalize firms for their carbon emissions, then why do firms choose to disclose them?" We posit that managers weigh the costs and benefits of disclosing carbon emissions and choose to disclose only if the perceived benefits of doing so outweigh the perceived costs. Accordingly, we also estimate the firm-value effects of the act of voluntarily disclosing carbon emissions. Using propensity score matching and doubly robust regression, we find that the median firm value is about $2.3 billion higher for firms that disclose their carbon emissions compared to firms that choose to not disclose them.

By providing scholarly evidence on the firm-value effects of carbon emissions, we supply managers with information that will help them make important decisions regarding the cost-benefit trade-offs of allocating resources to measuring, disclosing, and reducing carbon emissions. Our findings suggest that non-disclosure of carbon emissions may be costly for firms and is associated with a lower firm value, *ceteris paribus*. These findings are also important for boards of directors and managers because failure to integrate climate change into business strategy may reduce firm value (GS Sustain 2009).

Our findings are important to U.S. and international regulators and standard-setters as they work toward developing standards for measuring, assuring, and reporting on a firm's GHG statement. Our results suggest that capital markets incorporate information not only on the firm's choice to disclose its carbon emissions, but also on the level of these emissions. These valuations are consistent with demands by users and preparers for clearer guidelines from regulators and standard-setters for measuring and disclosing GHG emissions.

Of equal importance is the assurance of GHG emissions by an independent third party, which is currently not mandated in the U.S. Therefore, the firms in our sample choose whether to voluntarily disclose their emissions levels and, if they do so, then whether to provide assurance for their emissions and the type of assurance provider. Currently, many firms are required to have their carbon emissions assured, for example, by a public accounting firm, or verified by a governmental

[31] We also address the conjecture that the insignificant results for the $EPA = 0$ group in Table 4 are due to a lack of power. This conjecture is corroborated by analyses that (1) reduce the number of observations without reducing noise; (2) reduce noise only; or (3) reduce the number of observations as well as noise. Regarding (1), when we include *TRI* in Equation (1), we lose over 60 percent of the observations from the $EPA = 0$ group. With this loss in power, the coefficient on *TCO2* is not statistically significant. Regarding (2), when we winsorize the data at the 5 percent level, the coefficient for the $EPA = 0$ group is significant at $p < 0.10$. Regarding (3), using only December fiscal year-end firms better aligns the accounting data and the emissions data. The *TCO2* coefficient for the $EPA = 0$ group is significant at $p < 0.10$. Thus, our tests support our conjecture that the statistically insignificant results for the $EPA = 0$ firms are due to a lack of power.

agency, such as the EPA through their Climate Leaders program. Furthermore, other firms have their emissions monitored by internal auditors. Also, some of the firms in our sample have voluntarily joined self-regulatory organizations, such as the Chicago Climate Exchange or the California Climate Action Registry, which require independent third-party assurance. This diverse institutional context points to the important role played by U.S. and international regulators and standard-setters in considering whether to require more uniformity in the assurance of GHG emissions with the goal of increasing the reliability of this information.

Having found evidence of a negative association between carbon emissions and firm value, in future research we plan to examine the association between carbon emissions and components of firm value. Another potentially fruitful area of research could address the challenges surrounding assurance of carbon emissions. Currently, the extent of independent third-party assurance and what constitutes assurance are ill-defined (Simnett et al. 2009b). International accounting research on assurance of GHG emission statements is gaining momentum (Zhou, Green, and Simnett 2012; Huggins, Green, and Simnett 2011), thus pointing to the increasing relevance of this issue. As more years of data become available from private and publicly available sources, future research could examine the value of assurance of carbon emissions and the association between assurance of carbon emissions and market value.

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APPENDIX A

Variable Definitions

MKT	=	market value of common equity at the end of the calendar year, calculated as: SHROUT ∗ PRC (in $ millions), where (SHROUT ∗ PRC) = common shares outstanding multiplied by price per share;
TCO2	=	total carbon emissions in metric tons for year *t* (in thousands);
ASSET	=	book value of the firm's total assets (AT) at the end of fiscal year *t* (in $ millions);
LIAB	=	book value of the firm's total liabilities (LT) at the end of fiscal year *t* (in $ millions);
OPINC	=	firm's operating income (in $ millions) after depreciation (OIADP) for fiscal year *t*;
CNCRN	=	number of damaging ratings (concerns) for the firm identified in KLD;
STRNG	=	number of proactive ratings (strengths) for the firm identified in KLD;
PROPDISCL	=	ratio of the number of firms in the two-digit SIC industry code with publicly available carbon emissions to the total number of firms in the industry in our sample;
SIZE	=	log of the firm's total assets at the end of the fiscal year;
MF	=	number of management forecasts issued by the firm during the year;
BM	=	firm's book-to-market ratio;
LEV	=	firm's leverage, measured as (DLTT + DLC)/(DLTT + DLC + CEQ);
II	=	percentage of total shares outstanding held by institutional investors, from the Thomson Reuters 13-F database;
FRNSALE	=	firm's foreign sales as a percentage of total sales for the year, from the Worldscope database;
EPA	=	an indicator variable equal to 1 if the firm operates in an industry that will be required by the EPA's GHG Mandatory Reporting Rule to report its GHG emissions, and 0 otherwise; and
DISC_CDP	=	an indicator variable equal to 1 if the firm discloses its carbon emissions to the CDP and to the public, and 0 otherwise.