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IS THE TAIL WAGGING THE DOG?

AN EMPIRICAL ANALYSIS OF CORPORATE CARBON FOOTPRINTS AND FINANCIAL PERFORMANCE

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ABSTRACT

There is a long-standing debate in the business strategy literature over whether or not firms profit from improving their environmental performance. However, the existing literature has focused mostly on regulated emissions data and few studies have included climate change in this debate or taken a life cycle analysis approach to defining environmental performance. This study investigates the impact of greenhouse gas emissions (GHG) on corporate financial performance, and develops complementary hypotheses based on accounting and market based corporate performance measures to represent a short term and long-term perspective on financial performance. Our study also includes both direct and supply chain GHG emissions in calculating a firm's carbon footprint. In doing so, this paper addresses important questions concerning the profitability of environmental initiatives within the context of supply chain management. Our empirical analysis is based on a novel longitudinal database including over 1100 US firms across a range of industries for the 2004-2008 period. Our results reveal that increasing carbon emissions positively impact financial performance when using accounting based measures (ROA) while it has a negative impact on market based measures of financial performance (Tobin's q). Importantly, supply chain carbon emissions are shown to significantly drive these findings.

INTRODUCTION

There is a long-standing debate in the business strategy literature over whether or not firms profit from improving their impact on the natural environment and society in general (Margolis and Walsh, 2003; Orlitsky, Schmidt and Rynes, 2003; Ambec and Lanoie, 2008). Since the initial study by Bragdon and Marlin (1972), more than167 published studies have sought to answer this research question using empirical methods while at least 16 review papers have attempted to parse their findings (Margolis, Elfenbein and Walsh, 2007). In contrast to prevailing economic reasoning, many of these studies show companies with higher environmental standards outperform dirtier firms, indicating the existence of a ‘win-win’ relationship between business and the environment (Dowell, Hart and Yeung, 2000; King and Lenox, 2002). However this literature has relied strongly on subjective ratings to proxy environmental performance. Where objective, end-of-the-pipe measures of environmental damage (e.g. pollutant emissions) have been available, researchers have focused on a heavily regulated subset of industries. With rare exception have researchers tested their hypotheses with climate-related emissions, which are still largely unregulated yet subject to increasing public scrutiny (Ziegler, Busch and Hoffman, 2009). Accordingly, the literature has yet to answer the important question of whether firms profit from reduced emissions without regulatory or legislative mandates to do so. Answering this question is important to understanding the strategic response of firms to the issue of climate change, where the regulation of carbon is currently at the center of a global policy debate and its regulatory future uncertain.

Furthermore, existing research has relied heavily on a circumscribed conceptualization of environmental performance, wherein a firm’s environmental damage is not considered if it occurs beyond traditional enterprise boundaries. To our knowledge, no empirical analysis has employed an environmental life cycle analysis (LCA) perspective to account for a firm’s upstream environmental performance and its relation to financial performance. This is surprising considering the emissions that a firm produces through its supply chain are often much greater than its direct emissions. For example, the supply chain is estimated to be responsible for nearly two thirds of all hazardous waste generated in major US economic sectors (Rosenblum, Horvath and Hendrickson, 2000). Nonetheless, research attempting to uncover the firm-level financial impacts of environmental performance has yet to transcend organizational boundaries. Should it be assumed that corporate performance is affected only by emission sources under a firm's direct control without considering the supply chain? Orr could the tail be wagging the dog?

Within the strategic management literature, scholars have increasingly emphasized the supply chain as an important unit of competitive advantage (Kotabe, Martin and Domoto, 2003; Hult, Ketchen and Arrfelt, 2007). Several authors have pointed out that greening the supply chain also has the potential to affect financial performance and that further research is needed in that area (Bowen, Cousins, Lamming and Faruk, 2001; Rao and Holt, 2005; Zhu, Sarkis and Geng, 2005). In this paper, we respond to this call by examining both the effect of direct *and* supply chain carbon emissions on financial performance.

Our study uses data on greenhouse gas (GHG) emissions from a firm's entire value chain to test the effect of direct and supply chain emissions on complementary measures of financial performance. Carbon is embedded in the numerous energy inputs of a firm's product or service and released as carbon dioxide from multiple sources throughout the supply chain. Several other climate change forcing GHGs, such as methane and nitrous oxide, are also emitted from range of upstream economic activities (Kolk, Levy and Pinkse, 2008). Not surprisingly, a recent life cycle assessment estimates that 85 % of the average firm total carbon footprint comes from supply chain sources (Mathews, Hendrickson and Weber, 2008).[1] The carbon 'footprint' perspective thus extends the pays to be green debate by investigating the relationship between environmental and financial performance using a more thorough evaluation of firm-level impacts

[1] Mathews, Hendrickson and Weber (2008) define carbon footprint to include only direct and upstream carbon emissions; downstream carbon emissions from the use and disposal phase are not included. This study uses the same boundaries as Mathews et al. (2008) to define carbon footprint. Similarly, the term 'value chain' in this study includes only direct and upstream processes.

on the natural environment. In doing so, we engage a growing literature that emphasizes the importance of the supply chain to understanding the environmental implications of industrial systems (Hall, 2000). This literature takes the discussion of environmental management beyond firm-level boundaries, assessing the characteristics, potential and challenges of green supply chain management practices (Bowen et al., 2001; Vachon and Klassen, 2006; Darnall, Jolley and Handfield, 2008; Seuring and Muller, 2008; Delmas and Montiel, 2009). The green supply chain research, however, has evolved largely in isolation of the "pays to be green" debate and little integration exists between these related streams of research (Bowen et al., 2001; Rao and Holt, 2005).

We also investigate the relationship between carbon performance and financial performance from both an accounting and a market-based perspective. An accounting view of financial performance assesses only tangible costs and revenues and implicitly assumes factors that affect profits, namely climate regulation, are fixed. In contrast, in a market-based perspective of financial performance, future cash flows and profitability can be estimated to reflect the likelihood of more stringent climate regulation in the near future. These complementary measures of performance allow us to comprehensively examine the relationship between carbon emissions and financial performance during a period of increasing public sector concern for climate change issues as well as heightened investor scrutiny (Kolk and Pinkse 2004; Lash and Wellington, 2007; Porter and Reinhardt, 2007).

Our contribution is to merge the literature on environmental and financial performance to the green supply chain literature by incorporating a LCA-based conceptualization of environmental performance into an empirical analysis of the impact of corporate GHG emissions on financial performance. In doing so, we extend the "pays to be green" literature to the relatively unexplored yet pressing issue of climate change. Our study is also the first to test whether firms have a financial incentive to mitigate the GHG emissions of their suppliers. This is achieved by leveraging novel longitudinal environmental impact data for over 1,000 US corporations from 2004 - 2008 to investigate the effect of direct and supply chain emissions on financial performance and by using different measures of financial performance. The results show that a firm's total carbon footprint can either have a positive or negative effect on business depending on whether we take an accounting or market-based view of financial performance. Importantly, we find that emissions from the supply chain have a strong impact of financial performance.

The following section reviews the existing literature on the link between financial and environmental performance and the extent to which the green supply chain literature addresses financial performance. In the next section, we develop hypotheses on how a firm's carbon footprint impacts financial performance. The methods section describes the database used to measure environmental performance, how the financial performance variables are constructed and the empirical methods used to test the hypotheses. The findings are presented in the results section, while the final section discusses these results and concludes the article.

LITERATURE REVIEW

Environmental and Financial Performance

Understanding the relationship between corporate social performance and financial performance has been the focus of considerable research since the 1970s (Margolis and Walsh, 2003; Orlitsky et al., 2003; Ambec and Lanoie, 2008). Within this wider context, many scholars have investigated whether or not firms are financially rewarded for improving environmental performance. The conventional answer to this question, derived from neoclassical microeconomics, is that any investment in the natural environment comes as an additional cost to firms and detracts from profit maximization (Friedman, 1970). Without clearly defined ownership rights of a public good such as air or water quality, society incurs the cost of a firm's pollution and for a firm to voluntarily internalize these costs would be tantamount to philanthropy.

An emerging body of research, however, has recently challenged this long-standing assumption. Proponents of a "win-win" theory (see Porter and van der Linde, 1995) claim improving environmental performance evinces latent profit opportunities. From an extensive review of the existing literature, Ambec and Lanoie (2008) find theoretical arguments supporting several distinct opportunities for firms to either increase revenue or reduce costs by improving their impact on the environment. For example, by switching to a more environmentally friendly production process, firms can gain access to new markets for 'green' products and/or differentiate themselves from their dirtier competitors while improving resource efficiencies and reducing costly wastes (Reinhardt, 1999). Similarly, research and development into greener production processes can lead to revenue generating or cost minimizing innovations that would otherwise be unexploited (Porter and van der Linde, 1995). An improved environmental image can also improve relations with external stakeholders (e.g. regulators, environmental NGOs, etc…) and mitigate risks often associated with these relationships (Reinhardt, 1999).

Scholars attempting to empirically test these theories and settle the debate have generated an extensive body of literature. The balance of studies suggest a positive relationship between improved environmental and financial performance (Margolis and Walsh 2003; Orlitsky et al., 2003; Ambec and Lanoie, 2008). However, empirically examining this research question confronts several methodological challenges that draw into question the confidence placed in the results of existing studies and any collective inference that may be gained. Environmental performance is a broad construct without well-codified parameters or objective evaluation criteria and scholars have lacked the data to adequately quantify such a broad construct (McWilliams and Siegel, 2000; Brammer and Millington, 2008; Guenster, Bauer, Derwall, and Koedijk, 2010). Studies using econometric estimation have relied on subjective environmental performance ratings produced by rating agencies (e.g. KLD, Council on Economic Priorities (CEP) and Innovest) or emissions data from heavily regulated (e.g. Toxic Release Inventory (TRI)) industries to approximate corporate environmental performance (Hart and Ahuja, 1996; Cohen, Fenn and Konar, 1997; Russo and Fouts, 1997; King and Lenox, 2002; Elsayed and Paton, 2005). The few studies which have had the longitudinal data necessary to confidently test both the sign and direction of the relationship between environmental and financial performance have focused on direct environmental impacts of firms from heavily regulated industries (Hart and Ahuja, 1996; King and Lenox, 2001; King and Lenox, 2002; Elsayed and Paton, 2005). Very few have examined unregulated pollutants, including GHG emissions, and it is unclear whether and how such pollutants affect financial performance. Furthermore, data on firm-level environmental performance has excluded the supply chain. Inference based on these data must therefore assume the effect of environmental performance on financial performance comes only from facilities under direct ownership of the firm. To the best of our knowledge, no studies have examined the validity of this assumption by including supply chain environmental performance in their model specification.

Few studies have empirically examined the relationship between corporate GHG emissions and financial performance. Despite the rising profile of climate change as a dominant environmental concern, prior research provides limited insight into how firms will respond to the challenge of improving their impact on the natural environment in a time when environmental performance is so strongly associated with climate change and GHG pollution. Recently, scholars have attributed a change in the strategic orientation of firms with regard to climate change to the specter of GHG regulation (e.g. emission permits, cap and trade, energy efficiency standards, etc…) and associated costs on carbon emissions(Kolk and Pinkse, 2004; Porter and Reinhardt, 2007). Indeed, research suggests efforts to manage carbon emissions can depend simply on the threat of regulation. Reid and Toffel (2009) find that firms headquartered in states with proposed climate legislation are more likely to respond to public pressure to gather and share information on carbon emissions. Similarly, the results of Ziegler et al. (2009) indicate the relationship between carbon management efforts and financial performance depends on the stringency of carbon regulation. Contrasting differing carbon policies between the European Union and the US their analysis shows returns of stock portfolios screened for proactive carbon management were abnormally high when subject to more stringent carbon regulation; the opposite was true for firms under weaker climate policies.

While the results of this study are a step toward understanding the effect of carbon emission on financial performance, they are based on qualitative answers to survey questions on management practices and do not necessarily reflect actual carbon emissions of the considered firms or their suppliers.

The Supply Chain

The definition of environmental performance in empirical studies has included only those activities close in space and time to a firm's final good or service. A more comprehensive notion of environmental performance is espoused by environmental LCA and embodied by concepts like ecological footprinting[2] (Mathews et al., 2008). A firm's environmental 'footprint' spans its entire value chain and its estimation requires a full life-cycle calculation. The climate change analog is the 'carbon footprint' where a firm's total carbon footprint includes both direct emissions and those induced in their supplier firms (Mathews et al., 2008). By expanding the traditional boundaries used to evaluate environmental performance, the footprint perspective raises questions regarding how firms should manage the environmental performance of their suppliers and how this impacts financial performance. Indeed, recent research has pointed to a strong reliance on supply chain strategy as a key source of competitive advantage, wherein competition is manifest at the inter-supply chain level rather than strictly between firms (Handfield and Nichols, 2002; Kotabe et al., 2003). It follows that the capacity of firms to outperform competitors depends on the collective strengths of suppliers; thus, managers overlooking the strategic importance of suppliers and their value-adding relationships fail to exploit a key source of competitive advantage (Hult et al., 2007; Hendricks and Singhal, 2003). Firms often ensure competitive supplier networks through imposing the adoption of management standards such as ISO 9000 on their suppliers and this has been shown to facilitate widespread diffusion of best management practices through supply chain networks at the global

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[2] A complete LCA calculation accounts for both the upstream (e.g. suppliers and raw materials) and downstream (e.g. use and disposal) environmental impacts of firm's good or service (Hendrickson, Horvath, Joshi and Lave, 1998). This study does not examine the downstream environmental impacts associated with the consumer use and disposal stage, restricting the boundary of our analysis instead to the firm and its upstream supplier network.

level (Corbett, 2006). Similarly, many scholars have noted the potential for customer firms to leverage their purchasing power to procure green suppliers and achieve environmental improvements at the industry level (Green, Morton and New, 1996; Lamming and Hampson, 1996; Delmas and Montiel, 2009). However, few studies have examined whether or not imposing environmental management standards on suppliers makes business sense.

The notion of redefining environmental management practice beyond traditional firm boundaries has received increasing attention as scholars explore the importance of the supply chain to understanding the environmental implications of industrial systems (Hall, 2000). From this has emerged a broadened concept of environmental performance wherein the supply chain is considered integral to successful environmental management systems and achieving sustainability goals (Green et al, 1996). Incorporating suppliers to environmental management strategies includes a range of practices related to improved environmental performance, including incorporating environmental criteria into purchasing decisions, manufacturing, distribution and reverse logistics (Bowen et al., 2001; Hervani, Helms and Sarkis, 2005; Zhu et al., 2005; Darnall et al, 2008, Delmas and Montiel, 2009). Yet while greening the supply chain have the potential to significantly improve impacts to the natural environment (Green et al., 1996; Zhu et al., 2005), it remains unclear what effect such efforts will have on financial performance (Hervani et al., 2005; Rao and Holt, 2005; Seuring and Muller, 2008). The literature provides some theoretical explanation with regard to the financial implications of greening the supply chain, predominately in support of a positive relationship. In addition to improving resource efficiency, extending environmental management beyond traditional organizational boundaries can benefit managerial decision making, facilitate the cultivation of strategic supply networks and mitigate environmental risks (to reputation and regulation) (Bowen et al., 2001). It is often the case that a firm's reputation depends on the industry as a whole and large customer firms have an interest in maintaining environmental performance of business partners and suppliers (King and Lenox, 2000). Zhu et al. (2005) claim that by managing the environmental performance of suppliers firms secure important sources of competitive advantage, such as market expectations, risk management, regulatory compliance and business efficiency. In this regard, the degree to which a firm's choice of suppliers allows for environmental innovation can be an important source of competitive advantage (Greffen and Rothenberg, 2000).

Only a small number of studies, however, have empirical tested whether firms actually profit from having green supply chains (Seuring and Muller, 2008). A study of the Spanish hotel industry finds support that efforts to green the supply chain relate positively to financial performance (Alvarez, Jimenez and Lorente, 2001). Similarly, Rao and Holt (2005) demonstrate a link between greening the supply chain and increased competitiveness and economic performance amongst manufacturing firms in South East Asia. On the other hand, Bowen et al. (2001) find firms with the least commitment to ensuring the environmental performance of their suppliers demonstrate higher short-term profitability compared to those actively greening their supply chain. However, this difference in performance was not shown to be statistically significant. In addition to conflicting results, the methodologies of these few existing studies limit inference on the link between green supply chains and environmental performance, as they rely on survey responses taken from relatively small samples of specialized industries. Studies focused specifically on modeling the link between green supply chains and financial performance are yet to employ econometric techniques using objective environmental performance data.

In summary, scholars have empirically investigated the relationship between environmental and financial performance for several decades without converging to a consensus answer to this research question and empirical studies have relied heavily on subjective third-party ratings of environmental performance, survey data, and regulated pollutants to test their hypotheses. Scholars have largely overlooked unregulated pollutants, in particular GHGs, and examined environmental performance within the larger issue of climate change. Furthermore, the "pays to be green" literature has been conducted almost exclusively within the boundary of the firm, despite a growing awareness of the importance and scale of the environmental impacts at the supplier-network level. This leaves unanswered questions regarding the economic justifications for corporate climate strategies aimed at reducing carbon emissions and whether efforts to extend the boundaries of such strategies to the supply chain pay off.

HYPOTHESES

In this section we develop two sets of hypotheses based on two complementary conceptualizations of financial performance. Their juxtaposition frames our proposal that a firm's total GHG emissions (i.e. both direct and upstream supplier GHG emissions) will have an opposite effect on financial performance depending on whether the measure of financial performance is derived from an accounting- (also described as backward-looking) or market-based (also described as forward-looking) conceptualization of financial performance. In each set of hypotheses we first focus on a firm's total GHG emission (i.e. the sum of direct and upstream supplier emissions). We then resolve the total GHG emissions to a finer level, focusing on how direct and supply chain emissions individually impact each measure of financial performance.

The accounting view takes into account only tangible costs and revenues and assumes factors that affect profits, namely climate regulation, are fixed. The market-based perspective of financial performance integrates estimations of a firm's future profitability under changing conditions, such as the uncertain regulatory future of GHGs and the possibility of a cost on carbon. The two measures of financial performance we use to approximate these perspectives are return on assets (ROA) and Tobin's q, respectively. Used as a traditional accounting measure, ROA will reflect only the tangible effects (e.g. costs, revenues, etc…) of environmental performance within each fiscal year and is not sensitive to costs which are external to the firm. In contrast, Tobin's q incorporates the market value of firms and is thus able to reflect intangible effects of environmental performance, such as investor perceptions and estimations of expected future cash flows (Konar and Cohen, 2001; King and Lenox, 2002; Busch and Hoffman, 2009).

Accounting-based View of Financial Performance

At the center of the "pays to be green" debate is a long-held assumption of an unavoidable trade-off between the social benefits of preserving a healthy environment and the private costs to business this entails. Proponents of neoclassical microeconomics maintain that devoting resources to environmental management detracts from the goal of maximizing shareholder wealth (Friedman, 1970). Environmental impacts are a negative externality, the costs of which are borne by society and do not affect measurements of firm profit (Reinhardt, 1999). Assuming environmental externalities are the only departure from perfect competition and there exists no government intervention, managing environmental performance in tantamount to volunteering to internalize social costs not faced by competing firms. It follows that under such circumstances it would be impossible for firms to profit from investments in environmental performance (Reinhardt, 1999).

In recent studies, scholars countering this view have provided evidence in support of a 'win-win' hypothesis wherein firms provide the social benefit of improved environmental performance at a profit (Hart and Ahuja 1996; Dowell et al., 2002; King and Lenox, 2001; King and Lenox, 2002). Firms can generate competitive advantage through proactive environmental strategies which decrease regulatory liabilities, mitigate business risks and/or appeal to important stakeholders (Porter and van der Linde, 1995; Reinhardt 1999; King and Lenox, 2002). Importantly, 'win-win' proponents also claim efforts to reduce pollution lead to enhanced financial performance by increasing process innovation and exposing inefficiencies. This line of reasoning, often referred to as the Porter Hypothesis (PH), is predicated on firms systematically miscalculating the cost and benefits of pollution abatement (Palmer, Oates and Portney, 1995; Reinhardt, 1999; Ambec and Lanoie, 2008).

Indeed, McWilliams and Siegel (2001) note there is an optimal level of pollution abatement beyond which a firm will begin to lose money and managers should treat an endeavor such as pollution abatement like any other investment, reducing emissions to the point where the marginal costs and benefits are equal. Subject to competitive market forces, the PH contradicts the assumption of a profit maximizing firm. To counter this, some 'win-win' scholars contend that by addressing one market failure (i.e. the pollution externality) environmental regulation mitigates additional market failures (e.g. asymmetric information within firms), allowing environmental costs to be offset. For example, the optimal level of pollution abatement is often underestimated because information on the benefits of pollution reduction is costly to obtain and the associated financial gains are regularly overlooked (Porter and van der Linde, 1995; King and Lenox, 2002). King and Lenox (2002) found that only by preventing waste — as opposed to expensive on-site treatment or third-party processing of pollution — can firms uncover process inefficiencies, reduce unnecessary costs and profit from pollution reduction. Indeed, the authors provide convincing empirical evidence that profitable toxic waste reduction in the manufacturing sector was driven solely by waste prevention strategies. While this corroborates the existence of unexploited efficiencies at the firm level, and supports the PH, it remains unclear whether this hypothesis proves true in the context of climate change and attendant regulatory uncertainty.

Carbon emissions are unregulated in the U.S., meaning firms are under no obligation to abate, gather information on or publicly disclose emissions levels. Without government intervention carbon emissions also have no marginal cost to firms. Moreover, few commercially viable options to reduce carbon emissions exist outside of prevention (Anderson and Newell, 2004; Riahi and Ruben, 2004), making it difficult to claim that the benefits of prevention are obscured by more costly end-of-the-pipe abatement or treatment alternatives. As carbon emissions are strongly coupled to energy consumption, managers already have a clear signal to optimize energy use without directly addressing climate change or their firm's carbon footprint. [3] Consequently, there are few unexploited resource efficiency gains and any additional efforts to cut energy use would most likely entail unnecessary costs that will be difficult to offset (Walley and Whitehead, 1994; Morgenstern and Pizer, 2007; Pinkse and Kolk, 2009).

This cost-based argument is also scalable to the supplier network level of analysis, extending beyond the boundaries traditionally used to analyze the relationship between environmental performance and financial performance. Scholars have increasingly recognized that successful management of the supply chain can be an effective means to secure competitive advantage (Hendricks and Singhal, 2003; Li, Ragu-Nathan, Ragu-Nathan, and Rao, 2006). Suppliers that independently devote resources to abate carbon emissions beyond optimal levels can pass the resulting unnecessary costs to downstream customers firms, detracting the value-added of their service or good. Regardless of internal carbon management practices, the increase in cost to the customer firm from the abatement efforts of its suppliers can compromise an integral part of a firm's advantage over competing firms at the supplier network level.

Meanwhile, a firm attempting to manage the carbon emissions of suppliers can also be costly especially in the short-term. Firms procure their supply chain networks based on concern for core activities (e.g. cost, quality and faster time-to-market) to maximize efficiencies and achieve competitive advantage (Vachon and Klassen, 2006). Meanwhile, Vachon and Klassen (2006) suggest concerns for supplier impacts to the natural environmental are eventually addressed only in the long-term once core-concerns are fulfilled. Monitoring GHG emissions across multiple tiers and a complex network of suppliers requires devoting additional resources to building corporate information systems to collect and process supplier data, while working directly with less-suppliers to ensure compliance and mitigate risk also requires considerable investment (Hervani et al., 2005). These non-core efforts often result in increased costs that are difficult to offset (Bowen et al., 2001), especially when carbon dioxide is already coupled to energy consumption.

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[3] According to the EPA, carbon dioxide constituted 85.4% of all GHG emissions in 2007; fuel combustion accounted for 94 per cent of the carbon dioxide emissions (US EPA, 2007).

We use ROA as an accounting-based measure of financial performance to set up our first hypothesis: without a cost on carbon emissions, or hidden efficiency gains from carbon abatement measures, firms will not be able to offset the costs of abatement measures directed at both direct and supplier emissions. Our first set of hypothesis thus follows:

Hypothesis statement 1A: *All else being equal, the more a firm decreases total GHG emission (i.e. both direct and upstream supplier emissions) the lower its ROA*

Hypothesis statement 1B: *All else being equal, the more a firm decreases direct GHG emissions the lower its ROA*

Hypothesis statement 1C: *All else being equal, the more a firm decreases its supply chain's GHG emissions the lower its ROA*

Market-based View of Financial Performance

Increased shareholder concern and awareness of corporate environmental performance can affect the perceived future financial performance of firms. Greener firms are better positioned to minimize future regulatory scrutiny and compliance costs, appeal to increasing consumer demand for environmentally friendly products and benefit from setting the industry standard that may act as a barrier to entry for competitors (Reinhardt, 1999). Researchers have shown the stock market to be responsive to news and information on firm-level environmental performance criteria. For example, on the day firms were first required to announce their TRI emissions Hamilton (1995) found significant negative abnormal returns for firms subject to this newly established regulation. Event studies have consistently demonstrated that poor environmental management result in decreased stock returns and that opposite is true for firms with superior environmental reputations (Hamilton, 1995; White, 1995; Klassen and McLaughlin, 1996). Studies using econometric methodology also provide evidence that the market values firms according to environmental criteria (Dowell et al., 2000; Konar and Cohen, 2001). More recent studies (e.g. Busch and Hoffman, 2009) suggest financial markets may be responding to increased corporate reporting of GHG inventories and the rise of climate change as the dominant environmental concern in the public's eye (Lash and Wellington, 2007; Porter and Reinhardt, 2007).

According to Porter and Reinhardt (2007) 'climate change is now a fact of political life…greenhouse gas emissions will be increasingly scrutinized, regulated and priced' (pg. 22). If the market expects carbon to be imminently regulated, a firm's carbon exposure (i.e. its GHG emissions) represents an intangible risk which will negatively affect the valuation of future expected cash flows. While the size of a firm's carbon footprint does not harm short-term profitability, the threat of carbon regulation can harm a carbon intensive firm's credit rating and financial markets may similarly devalue firms according to their carbon emissions (Busch and Hoffman, 2007; Lash and Wellington, 2007; Busch and Hoffman, 2009).

Shareholder resolutions asking for GHG emission disclosures are growing more common and shareholder coalitions, such as the Coalition for Environmentally Responsible Economies (Ceres) and the Carbon Disclosure Project (CDP), have recently formed to pressure greater transparency with regard to carbon emissions and carbon management strategies in order to inform asset valuation and investment decisions (Kolk et al, 2008; Makower, Pernick and Wilder, 2008; Pinkse and Kolk, 2009). The number of climate change-related shareholder resolutions filed between the years 2000 and 2007 increased almost 12-fold, while shareholder voting support for these resolutions has also increased significantly (Rindfleisch, 2008; Ceres, 2009). Such concern for transparency is also manifest in capital markets, where there are signs firm-value is increased by climate friendly practices. The HSBC Global Climate Change Benchmark Index, developed by HSBC as a reference index to measure the stock market performance of companies well-positioned to benefit from climate change mitigation efforts, has been shown to outperform key common benchmark indices, such as the MSCI World Index and Standard and Poor's 500 Index by approximately 70%, between 2004 and 2007 (HSBC, 2007). Similar funds which screen for climate friendly firms (e.g. Credit Suisse global warming Index and Amro climate change and environment Index) also claim to outperform standard stock market indices since their inception in the early 2000s.[4]

Shareholder demand for transparency is not limited to a firm's direct emissions; the investment community is also aware of the importance of upstream emissions (Porter and Reinhardt, 2007; Lash and Wellington, 2007). For example, the CDP — a prominent collaboration of over 200 institutional investors representing $55 trillion in assets — maintains carbon disclosures of a number of the largest firms worldwide and provides businesses with a carbon disclosure framework for their supplier firms. Recognizing the business risks of carbon emissions at the firm-level extend beyond corporate boundaries, the CDP recently extended their assessment of firm performance to include information on the carbon strategies of suppliers (CDP, 2010).

Demand for supply chain transparency by investors is not surprising, as a firm's supply chain strategies and initiatives can have a significant impact on shareholder value generation (Christopher and Ryals, 1999; Lambert and Pohlen, 2001; Hendricks and Singhal, 2002; Losbichler, Mahmoodi and Rothboeck, 2008). Hendricks and Signhal (2002) reveal a direct connection between supply chain performance and stock prices by showing a marked decline in stock prices of companies that announce supply chain glitches. Timme and Williams-Timme (2000) estimate that, for the average S&P 500 company, a one percent increase in revenue increases Market Value Added nearly as much as a 5 per cent reduction in supply chain costs. As government, investors and consumers are now more aware of the upstream carbon emissions from a firm's network of suppliers (Kolk and Pinkse, 2004; Lash and Wellingston, 2007), environmental management is an increasingly visible component of a firm's overall supply chain strategy and shareholder value is more closely linked to the upstream environmental performance of suppliers. It is

[4] http://holtindex.credit-suisse.com/pdf/CSGWM.pdf (accessed on Nov 30, 2010).

often the case that stakeholders attribute the environmental impacts of less conspicuous suppliers to their higher-profile customer firms (Rao and Holt, 2005; Vachon and Klassen, 2006). Poor performing suppliers can degrade the reputation of their downstream customers and increase the risk of regulatory action interrupting important operations (Delmas and Montiel, 2009). As such, firms are placing greater emphasis on environmental performance when procuring suppliers to mitigate upstream risk from environmental regulation and liabilities (Min and Galle, 1997; Vachon and Klassen, 2006). Similarly, suppliers are facing increasing pressure to adopt better environmental management practices (Walton, Handfield, and Melnyk, 1998; Darnall, 2006; Plambeck and Denend, 2008).

The practice of conveying environmental performance criteria, such as GHG emissions, to external parties is thus increasingly important to businesses throughout the entire value chain. This is reflected by an increasing trend in supply chain transparency: In the US automotive sector, the Big Three automakers (General Motors, Ford and Daimler-Chrysler) made a formal request of the their suppliers to adopt the ISO14001 environmental management standard by 2003 (Delmas and Montiel, 2009); The largest IT company in the world, Hewlett-Packard (HP), recently made public through their Global Citizenship Report a list of its largest suppliers (accounting for more than 90% of HP's spending) to increase accountability and transparency (HP GCR, 2008); Under a recently issued executive order, the US government — the nation's largest single buyer of goods and services totally more than $500 billion annually — will ask almost 600,000 businesses in its supplier network to disclose their GHG emissions (US GSA, 2010); In the retail sector, Wal-Mart – with more than $400 billion in annual sales — also announced the goal of eliminating 20 million tons of GHG emissions from its supply chain (Lash and Wellington, 2007; Rosenbloom, 2010).

Cognizant of the threat carbon emissions pose to business, such visible activities towards increased transparency provide a strong signal and source of information to investors seeking more accurate assessments of firms in the context of climate change. With both increased concern in the investment community for issues of climate change and growing transparency in carbon reporting, we expect the market to place a premium on reduced GHG emissions within the firm and throughout its supply chain. Using Tobin's q as a measure of financial performance which reflects the market's valuation and, thus, a more forward-looking representation of financial performance, we propose a second set of hypotheses:

> *Hypothesis statement 2A*: *All else being equal, the more a firm decreases total carbon emissions (i.e. both direct and upstream supplier emissions) the higher its Tobin's q*
>
> *Hypothesis statement 2B*: *All else being equal, the more a firm decreases direct carbon emissions the higher its Tobin's q*
>
> *Hypothesis statement 2C*: *All else being equal, the more a firm decreases carbon emissions in its supply chain, the higher its Tobin's q*

In conclusion, we expect increased GHG emissions to affect complementary views of firm financial performance in opposite ways. Our hypotheses are summarized in Table 1. Following an accounting perspective we expect a firm's efforts to decrease carbon emissions to negatively affect ROA. However, we predict that with signaling from businesses and greater transparency in GHG emissions reporting, investors and consumer concern for climate change will manifest lower market valuations for firms with higher emissions reflected in Tobin's q. Importantly, we also predict that these effects will result from both a firm's direct emissions as well as those from their supplier network.

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[Insert Table 1 about here]

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METHODS

Environmental Performance Data

The environmental performance data used was acquired from Trucost, an environmental data company. The data used for this study quantify a broad range of environmental impacts of a sample of 1,200 publicly traded US companies each year from 2004 through 2008. The variables cover both direct and supply chain activities, such as emissions and waste production, water abstraction, natural resource use and raw materials extraction. The time period of our study corresponds to a period of increased public awareness and intense policy debate concerning climate change and GHG emissions. Nonetheless, carbon remained unregulated in the U.S. during this period (Ziegler et al., 2009).

Trucost quantifies the environmental impacts and associated damage costs attributed to both sources (e.g. extraction, resource use) and sinks (e.g. waste, pollutant emissions) in multiple media types, with a total of 751 variables measured for each firm. Each variable is measured as a damage quantity (e.g. mass of pollutant or volume of water) and has a corresponding damage cost. Trucost determines the marginal costs from a review of environmental economics literature, which are vetted by an independent academic advisory panel. Where available, Trucost collects standardizes, and validates, company reported environmental impact data from company annual reports, corporate websites or other public disclosures. Where not disclosed publicly, data is calculated from global fuel use when valid, and in the absence of fuel use data is imputed by conducting a detailed sector breakdown of each firm and applying a proprietary input-output (IO) economic model based on government census and survey data, industry data and statistics and national economic accounts. Economic IO models estimate the amount of resources (and their associated environmental impacts) from all 426 sectors of the US economy required for a particular firm to produce one unit of its good or service (output) (Rosenblum et al, 2000). Economic IO models account for interactions between sectors and can be augmented to incorporate resource consumption and environmental damages, allowing for the delineation of environmental damage associated with each economic activity into direct and multi-level supply chain activities (Rosenblum et al, 2000; Mathews et al, 2008; Huang, Weber, and Mathews, 2009).

Trucost adapts this framework to estimate the environmental impacts of over 464 business activities or processes. By mapping each firm's operations to subset of these business activities, Trucost calculates the magnitude of each environment impact variable based on a firm's sub-sector revenue profile. This data is then further informed by inclusion by standardizing and including company reported data, natural resource use, etc... A firm's sub-sector profile is derived from the 6-digit North American Industrial Classification System (NAICS), and segmental revenue data acquired from company accounts. The data produced by Trucost thus measure the environmental impacts of a firm's direct operations, as well as those associated with all levels of its upstream supply chain. *Direct* environmental impacts include all pollutants released or natural resources used by operations owned or controlled by a company, while *indirect* impacts result from activities owned or controlled by the company's upstream suppliers. Companies are given the opportunity to vet the data produced by Trucost.

Each environmental impact variable is measured as a damage quantity, such as mass or volume, and a damage cost. For a particular variable, damage cost is the product of the damage quantity and a marginal environmental damage cost to society (i.e. the external cost not borne by the firm). The variables are distributed within seven broad categories of environmental issues: GHGs, general waste, heavy metals, natural resources, volatile organic compounds (VOC), water abstraction and other emissions.

The environmental data provided by Trucost for each firm are a combination of model estimates and standardized company reported data. Thus, the balance of environmental impacts which are imputed versus directly measured varies for each firm and, where high, may obscure unique firm-level characteristics important to our analysis. We control for variation in this ratio by including a disclosure control variable that captures whether a firm's environmental data was publicly available or disclosed versus imputed by Trucost (see the Control variable section below).

We add to the Trucost data environmental performance ratings for each firm produced by KLD Analytics. KLD rates the social performance of all firms listed on the Russell 3000 and are a commonly used source of corporate social performance data in academic research (Moon, 2007; Chatterji, Levine and Toffel, 2009). The KLD database includes ratings for environmental performance, which are divided into "strength" and "concern" categories. In contrast to tangible output-based measures of environmental impact KLD ratings reflect process-based environmental performance (e.g. managerial practices and reputation).

Finally, these data are merged with firm financial performance data from Compustat's North American database. All the companies listed in the Trucost database were available in Compustat. Less than one percent of firms from the Trucost sample space were not found in the KLD's universe of firms and were subsequently dropped from the analysis. The use of panel data analysis methods further restricts our sample to firms with at least two consecutive years of complete data. After dropping any additional observations with missing values the sample contains 1,100 firms.[5] Figure 1 shows the firm distribution by industrial sector.[6]

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[Insert Figure 1 about here]

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[5] The sample space differs with respect to the choice of dependent variable: The number quoted her corresponds to the ROA; Tobin's q reduces the number of firms to 877. See the Dependent Variable section for more detailed explanation.

[6] We use the industrial classification benchmark (ICB) system created by Dow Jones Index and FTSE and adopted by Trucost.

Dependent Variables

The Compustat database is used to generate two financial performance variables: return on assets (ROA) and Tobin's q. ROA is a standard accounting measure of financial performance which is calculated by dividing earnings before interest by total sales (King and Lenox, 2002). Tobin's q is defined as the ratio of a firm's market value to the replacement cost of its assets, which this study approximates using the method developed in Chung and Pruitt (1994).

ROA and Tobin's q reflect complementary information regarding a firm's financial performance, which differentially capture the effect of environmental performance. While the former demonstrates how efficiently a firm generates profit per unit of production (i.e. accounting-based), the latter reflects intangible measures of performance, like investor confidence and reputation (i.e. market value) (Dowell et al, 2000; Konar and Cohen, 2001; King and Lenox, 2002). In this sense, Tobin's q can incorporate how robust the market interprets a firm to be in the face of future carbon legislation, whereas ROA only acknowledges a firm's carbon footprint indirectly via the efficiency of its use in producing earnings (Busch and Hoffmann, 2009). This is an important distinction in the context of our analysis, as carbon emissions did not have a price during our study period. Both measures are consistent with the preponderance of empirical research into the effect of environmental performance on financial performance (Dowell et al. 2000; King and Lenox 2002; Elsayed and Paton, 2005).

Calculating Tobin's q requires a relatively high number of financial variables and is more susceptible to missing values compared to ROA. This creates a discrepancy in the number of observations for each dependent variable in this study, resulting in asymmetric sample spaces (see Tables 4 and 5). To check whether this introduces sample bias, an identical analysis is conducted on the set of observations common to both dependent variables. The results are robust to both sample spaces.[7]

Independent Variables

The GHG emissions used as the explanatory variable in this analysis account for all six Kyoto Protocol GHGs and three additional compounds known to contribute to the greenhouse effect: Methly Chloroform, Tetrachloromethane, and Bromotrifluoromethane. Each of these nine GHGs is converted into C02-equivalent (C02-e) emissions based on Global Warming Potential factors and are measured in units of mass.

We use three main independent variables to define a firm's carbon footprint: Total, direct and supply chain GHG emissions based on the Greenhouse Gas Protocol, which is it the most used international greenhouse gas accounting tool (Ranganathan, Corbier, Bhatia, Schmitz, Gage, and Oren, 2004). *Total GHG emissions* are the aggregate CO2-e emissions from both of direct and supply-chain operations. Direct and supply chain emissions sources are determined in accordance with the GHG Protocol, which categorizes emissions into three categories. Scope 1 emissions are all GHGs emitted from sources directly owned or operated by the responsible firm; Scope 2 includes all indirect emissions resulting from purchased electricity, heat or steam; and Scope 3 emissions include all other sources. This study defines *direct GHG emissions* synonymously with Scope 1. S*upply chain GHG emissions* is defined as the sum of both Scopes 2 and 3. Natural log transformations were applied to adjust skewed distributions.

Controls

Five additional environmental issues from the Trucost database are included as control variables. These variables account for the range of disparate environmental impacts resulting from each firm's operations;

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[7] Results available upon request from the authors.

their inclusion allows our analysis to examine the effect of GHGs on financial performance while assuming all other sources of environmental performance variation are constant. Each environmental issue aggregates a unique subset of Trucost's environmental impact variables under the following categories: general waste, heavy metals, natural resources, volatile organic compounds (VOC), water abstraction, and other emissions. The variables *water abstraction, general waste, and VOCs* aggregate environmental damage quantities (e.g. mass or volume). The remaining environmental issue variables aggregate environmental damage costs, since these issues otherwise lack a common measure of damage quantity. The *other emissions* variable was dropped from our analysis due to collinearity with GHG emissions. To explore collinearity concerns raised by relatively high pair-wise correlations between several of these environmental control variables (see Table 2), we conduct identical analyses excluding the VOCs and general waste variables. Their inclusion does not alter the results or indicate the presence of collinearity. Moreover, the range of variance inflations factors (VIF) for the environmental control variables are within acceptable limits.

As mentioned above, we include a binary *disclosure* variable to account for variation across firms in whether environmental data was imputed versus publicly available or provided by the firm. This variable allows our analysis to control for any potential bias accorded companies based on their disclosure of environmental impact data. Approximately 21 per cent of the firms in our sample disclosed information on their environmental performance; however, although this percentage varies considerably across industries (e.g. less than 5 per cent disclosed performance data in the Financial sector versus greater than 60 per cent in the Utilities and Oil and Gas sectors).

Our analysis includes several financial variables to control for sources of firm-level heterogeneity, which are consistent with previous studies of financial and environmental performance (Dowell et al, 2002; King and Lenox, 2002; Elsayed and Paton, 2005). Firm total assets are used to account for variation in *firm size*, while *risk* is approximated by the ratio of total debt to total assets (i.e. leverage). Although total sales have been commonly used in the literature as a proxy for production, high collinearity with the GHG emissions variables precludes its use in this analysis. In its place *growth*, defined as the annual change in sales divided by total sales, is included to control for variations in production (King and Lenox, 2002). Capital expenditures divided by total sales is used as a measure of *capital intensity* (King and Lenox, 2002; Elsayed and Paton, 2005). To correct for skewed distributions, each of the financial control variables are transformed using the natural logarithm.

We create a KLD strength variable as the sum of all environmental *strength* items, and similarly created a KLD concern variable as the aggregate of all *concern* items (Chatterji et al., 2009). These variables were included as controls to account for any effect process-based environmental performance variables could have on financial performance (Harrison and Freeman, 1999; Chatterji et al, 2009). Industry dummy variables are included for each of the 10 Industrial Classification Benchmark (ICB) Industry sectors to control for sectoral effects. Finally, we use year dummy variables to account for trend effects.

Data Analysis

Panel data includes observations on N cross-section units (e.g. firms) over T time periods. As panel data analysis uses variation in both these dimensions it is considered to be one of the most efficient analytical methods for econometric data (Asteriou, 2006). Panel data analysis differs from regular time series or cross-section regression differs; rather it is conducted using fixed or random effects model estimation. These are competing models based on contradictory assumptions. Both models start from the general form:

$$y_{it+1} = \alpha_i + \beta X + \mu_{it}\,,\ i = 1,\ldots,N;\ t = 1,\ldots,T$$

where y_{it} is the financial performance of firm i in year t, α_i the unobserved firm-level effect, and β the vector of estimated regression coefficients for each of the explanatory variables measured in the matrix, X (Woolridge, 2006).

The models differ with respect to the definition of the unobserved effect. Fixed effects models define α_i as a "fixed" constant unique to each firm. Estimating the fixed effects controls for all unobserved firm characteristics but reduces estimation efficiency. Random effects methods, on the other hand, achieve greater efficiency by assuming the unobserved effect can be randomly assigned to each firm. If this assumption is invalid, however, random effects estimation will be inconsistent (Baltagi, 2005). The Hausman Test is widely used to examine whether this assumption is met for the model.

Although the Hausman test is frequently used to help researchers determine the more appropriate model, additional features of the underlying panel data can also inform model choice (Baltagi, 2005; Elsayed and Paton, 2005). For example, as the fixed effect captures all time-invariant variation at the firm level, robust estimation from fixed effects methods depends on adequate temporal variation in the explanatory variables (Baltagi, 2005). To cite an illustrative example, Dowell et al. (2000) were forced to restrict a portion of their analysis to random effects methods due to insufficient variation in their environmental performance variable.

RESULTS

The descriptive statistics are presented in Table 2 and Table 3 contains the correlation matrix for the regression variables. Figure 2 shows mean total GHG emissions (tons CO2-e) by sector in our sample and the contribution to this total from direct and supply chain sources. The Utilities, Oil and Gas, and Basic Materials industries in our sample stand out as the most carbon-intensive sectors. However, the distribution of emissions from direct and supply chain sources differs for each. Not surprisingly, Utilities produce markedly more direct emissions compared to their supply chain. In contrast, the mean ratio of supply chain to direct emissions is greater than unity for Oil and Gas industry, while average emissions are evenly distributed between direct and indirect sources for firms operating in the Basic Materials industry.

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[Insert Table 2 and 3 about here]

[Insert Figure 2 about here]

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In total, eight regression analyses were conducted and the results are tabulated in Tables 4 and 5. Models 1- 4 are the fixed and random effects estimations using ROA as the dependent variable. The coefficient estimations for GHG emissions variables in these first four models are markedly similar, despite the difference in regression estimation methods. Models 1 and 2 estimate the effect of *Total GHG Emissions* on firm ROA using fixed and random effects regression, respectively. Both models produced a positive and statistically significant ($p < .05$) coefficient for *Total GHG Emissions*. The effects on ROA from direct and supply chain GHG emissions are estimated in Models 3 and 4. Both show a positive and statistically significant ($p < .05$) coefficient for *Supply Chain GHG Emissions*. These results suggest that by decreasing their total GHG emissions by one per cent firms decrease their ROA by 0.00019 according to both estimation methods. Interestingly, a change in direct emissions does appear to affect ROA, while a one per cent decrease in supply chain emissions decreases ROA by 0.00019 (0.00026) based on fixed (random) effects estimation. Thus, hypothesis 1A and 1C are supported regardless of estimation method, while hypothesis 1B is not supported.

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[Insert Tables 4 and 5 about here]

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The regression results using Tobin's q as the dependent variable are shown in Models 5 – 8 (see Table 5). In contrast to the ROA results, the coefficient estimated by fixed effects is negative and statistically significant ($p < 0.01$) for *Total GHG Emissions*; random effects estimation does not show this variable to affect Tobin's q. Using the Hausman test to differentiate between these two models, fixed effects estimation is shown to be the more reliable estimation method[8]. Fixed and random effects estimation also produce conflicting results when the *Total GHG Emissions* is separated into direct and supply chain sources (models 7 and 8). Model 7a shows *Supply Chain GHG Emissions* to be negative, while *Direct GHG Emissions* have no effect on Tobin's q. In contrast, random effects (model 8) estimates *Direct GHG Emissions* to be negative and significant while *Supply Chain GHG Emissions* have no effect (model 8). Again, the Hausman test statistic for models 7a and 8 favors the fixed effects results ($p < 0.001$). Accordingly, our analysis predicts a decrease in a firm's Tobin's q of 0.008 to result from a one per cent increase in the size of its total carbon footprint. Similarly, a one percent decrease in carbon emissions specifically from a firm's suppliers improves its Tobin's q by 0.008. The results of models 5 and 7a support hypotheses 2A and 2C, respectively.

While the results of model 7a do not appear to support hypothesis 2B, it is important here to note the high correlation coefficient (0.77) between *Direct GHG Emissions* and *Supply Chain GHG Emissions* variables (see Table 2). To test for pairwise collinearity we repeated the fixed effects analysis, keeping direct and supply chain variables mutually exclusive (models 7b and 7c, respectively). The coefficient estimates for these two variables are robust to sign change; however, their high correlation indicates inflated standard error estimates (and p-values) in model 7a, which may conceal the significance of *Direct GHG Emissions.* As suspected, with *Supply Chain GHG Emissions* omitted (model 7b), *Direct GHG Emissions* remains negative but becomes statistically significant ($p < 0.01$) in support of Hypothesis 2B.

Regarding the control variables, *Water Abstraction* is the only environmental impact control variable to show statistical significance, which models 3 and 4 estimate to be positive. *KLD concerns* has a positive

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[8] The Hausman Test also shows fixed effects to be more accurate for the ROA regressions, but as the results are robust to both estimation methods the differentiation is redundant.

and significant effect on Tobin's q when estimated by random effects methods (models 7 and 8). Looking at the financial variables used to control for firm-level attributes, the estimates for *firm size* and *growth* are all statistically significant and their signs (negative and positive, respectively) constant across all models. These results are consistent with similar antecedent studies (see King and Lenox (2001), King and Lenox (2002) and Elsayed and Paton (2005)). Interestingly, *Disclosure* does not have an effect on ROA, regardless of estimation method. Random effects estimation shows Disclosure to positively affect Tobin's q, but is insignificant in the fixed effects models.

DISCUSSION AND CONCLUSION

Scholars have rarely looked beyond the boundaries of the firm when evaluating environmental performance. Moreover, very few studies have examined the "pays to be green" debate in the context of climate change and very little empirical evidence exists to elucidate the relationship between GHG emissions and financial performance. Our analysis is motivated by the opportunity to extend the definition of environmental performance to include a firm's supply chain and to explore the question of whether it pays to be green at a time when climate change is an increasingly dominant environmental concern. Using complementary perspectives of financial performance, our analysis examines how corporate GHG emissions impact financial performance and how this effect can be attributed to direct and upstream supply chain sources.

In general, our results show a significant relationship between a firm's total carbon footprint, which includes all upstream emissions of GHGs attributable to a firm's product or service, and financial performance. The direction of this relationship depends on whether the conditions affecting financial performance are considered from an accounting or market-based perspective. All else being equal, firms with lower carbon footprints earn smaller ROA, supporting the prevailing microeconomic viewpoint that profit-maximizing firms cannot improve the bottom-line by providing the social benefit of lower emissions. This reasoning also appears to be true for a firm's supply chain. Disaggregating each firm's total carbon footprint into direct and supply chain emissions reveals that increased emissions from a firms supply chain also increases ROA. Interestingly, no significant effect on ROA is found for direct carbon emissions.

At the same time, we find that an increase in the size of a firm's carbon footprint leads to reduced Tobin's q values. Unlike ROA, Tobin's q reflects the market's valuation of the firm and captures investors' perceptions of long-term profitability against the backdrop of regulatory uncertainty and shifting public concern for climate change. We reason the negative relationship comes from the market's discount of future expected cash flows for firms most threatened by the regulatory uncertainty of GHGs and climate change issues. Our analysis indicates both increased direct and supply chain carbon emissions negatively affect this market-based view of financial performance.

These results provide evidence that, according to an accounting-based perspective, a firm is financially penalized for decreasing its GHG emissions. This confirms that in the absence of carbon regulation, firms do not — either directly or through their network of suppliers —internalize tangible carbon costs. Contrary to many recent studies, this evidence does not support the Porter Hypothesis that firms stimulate profitable innovations and uncover process inefficiencies by investing in pollution mitigation. We can thus infer from the accounting-based perspective that firms currently have no financial incentive to minimize their suppliers' GHG emissions. However, our study also indicates that the market places a premium on reduced GHG emissions at both the direct and supplier network-level. This implies that investors wary of future carbon regulation and changing public attitude towards climate change, do not assess a firm's value in isolation of the environmental performance of its suppliers.

It is interesting that our results show direct carbon emissions have no effect on an accounting-based view of financial performance. Firms are becoming increasing aware of the strategic importance of climate change and carbon management strategies (Kolk and Pinkse, 2004; Porter and Reinhardt, 2007). This neutral effect suggests firms may be able to implement carbon reduction strategies to the point where the marginal cost of abatement is balanced by the marginal benefits (McWilliams and Siegel, 2001; Elsayed and Paton, 2005), while such optimal abatement levels have not been achieved by firms in the supply chain. This may be due to the relative ease of implementing carbon management policies within the boundaries of a firm versus extending such efforts upstream throughout a network of suppliers. An insignificant relationship between environmental performance and financial performance is also consistent with many of the findings from prior studies identified in Margolis and Walsh (2003). Nonetheless, our analysis confirms that the environmental performance of a firm’s supply chain significantly affects financial performance across two complementary measures of financial performance. This is also the case for the aggregate environmental performance of both a firm’s direct and supply chain dimensions. Whether or not the effect is positive depends on how financial performance is measured. This apparent contradiction can be explained, at least in part, by the fact that GHG emissions appear to be on the cusp of regulation and subject to growing public scrutiny and demands for transparency from investors Thus, although carbon emissions may currently have no short-term cost to firm’s this may not be the case on a longer time horizon where high polluting firms may be encumbered by regulation and public pressure to mitigate climate change impacts.

The results of this study have important implications for how firms conceptualize their environmental management systems and develop climate change strategies. An important decision companies face in managing their carbon footprint is whether to focus on their own operations and/or their supply chain (Kolk and Pinkse, 2004; Lash and Wellington, 2007; Porter and Reinhardt, 2007). Incorporating suppliers into an environmental management system hinges strongly on managers having an economic justification to do so. While there is increased awareness of the potential effectiveness of extending environmental management practices upstream, few firms have implemented such programs (Bowen et al. 2001; Rao and Holt, 2005). Several studies have examined the barriers to adopting such practices. In a survey of

Chinese manufacturing firms Zhu et al. (2005) found that despite the perception of green supply chain practices as having a positive influence on environmental performance, managers did not believe their added economic value could offset costs. Hervani et al. (2005) suggest acquiring measurements on the performance of an often complex and multi-tiered network of suppliers necessary to effectively management environmental performance are difficult to obtain and their economic benefits easily obscured.

Indeed, existing studies provide little evidence on the relationship between a firm's GHG emissions and financial performance. Nor does the literature indicate how far along a firm's value chain the economic benefits of carbon management reach. Our study suggests that internally focused measures to reduce emissions may not be the only way to increase market value and that firms should also consider the supply chain in any climate change strategy. As a policy corollary, firms with a financial incentive to integrate GHG performance concerns into their purchasing strategy can stimulate environmental innovation in suppliers. Taking into account the magnitude of inter-corporate trade, upstream environmental initiatives focused on the supplier network can be a powerful driver of environmental performance at the industry level, possibly even more so than green consumerism (Green et al., 1996). Wal-Mart, for example, has set the target of reducing 20 million tons of carbon from supply chain sources over a five year period and through other sustainability initiatives aimed at suppliers has created a strong market signal to prospective vendors to pursue green credentials (Rosenbloom, 2010; Plambeck and Denon, 2008). On the other hand, our study suggests that from an accounting-based perspective firms will be penalized for reducing their GHG emissions. This challenges the viability of voluntary carbon reduction agreements as a policy tool to effectively address climate change and suggests government involvement is necessary for firms to reduce their emissions.

This study makes several important and novel contributions to the literature on financial and environmental performance. We extend the debate into the realm of climate change and employ a perspective informed by environmental LCA to build on the definition of environmental performance. By including both supply chain and direct GHG emissions in the calculation of a firm's carbon footprint the scope of our analysis also illuminates the financial implications of environmental supply chain management, addressing the dearth of empirical research in this area. Leveraging a novel longitudinal database containing extensive environmental performance measures for over 1,100 companies from 2004 through 2008, our analysis indicates that a firm's carbon footprint significantly affects financial performance. Importantly, our study is one of the first to provide evidence that financial performance is affected by the environmental performance of a firm's supply chain. With regard to climate change, these findings provide the first clear signal from the literature that firms have a financial incentive to manage not only their own GHG emissions but also those of their suppliers. This paper illustrates the need for researchers to consider the entire value-chain when analyzing the debate over whether or not it pays to be green. As our study shows, it may be a case of the tail wagging the dog.

The study period for our analysis corresponds to a unique regulatory environment for GHGs. We demonstrate that this can affect the answer to whether or not it pays to be green through the choice of dependent variable. Although we attribute this to the simultaneous absence and threat of carbon regulation, it is not possible to directly infer from analysis what effect environmental regulation has on financial performance. The role of regulation in the pays-to-green debate represents an important area of future research, especially with regard to evaluating the strategic approach to climate from both a business and policy perspective. As pressure mounts at the international, national and sub-national levels to enact climate change policies, corporate carbons emissions represent a promising opportunity to investigate how environmental regulation modulates the relationship between environmental and financial performance.

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Table 1 Hypothesis Summary: impact of decrease GHG emissions on financial performance

Financial Performance	**Decreased GHG Emissions**		
	Total GHG Emissions	Direct GHG Emissions	Supply Chain GHG Emissions
Short-term (ROA)	-	-	-
Long-term (Tobin's q)	+	+	+

Table 2 Descriptive statistics

Variable	*Description*	*Mean*	*Standard deviation*	*Min*	*Max*
Return on Assets	Earnings before interest over total firm assets	0.05	0.10	-1.24	0.95
Tobin's Q	Market value of assets divided by book value of assets	1.75	1.56	-0.78	36.13
Total GHG Emissions	Log of total GHG emissions (tons $C0_2$-equivalent)	13.45	2.05	3.88	19.64
Direct GHG Emissions	Log of GHG emissions from sources directly owned or operated by the responsible firm (tons $C0_2$-equivalent)	11.21	2.79	-16.12	18.87
Supply Chain GHG Emissions	Log of GHG emissions from all sources other than those owned or operated by the responsible firm(tons $C0_2$-equivalent)	13.11	1.84	3.75	19.12
Water Abstraction	Log of direct water abstraction (volume)	8.19	8.23	0.00	24.71
General Waste	Log of directly generated general waste (mass)	9.03	2.04	0.00	15.15
Volatile Organic Compounds (VOC)	Log of directly produced of VOCs (mass)	4.46	2.69	0.00	14.12
Heavy Metals	Log of damage costs (millions $US) due to environmental release of heavy metals	-4.27	4.48	-16.12	6.00
Natural Resources	Log of damage costs (millions $US) due to direct natural resource use and extraction	-15.00	4.31	-16.12	8.70
KLD Environmental Concerns	Sum of all environmental concerns from the KLD Social Ratings Index	0.40	0.89	0.00	5.00
KLD Environmental Strengths	Sum of all environmental strengths from the KLD Social Ratings Index	0.23	0.62	0.00	4.00
Disclosure	Binary variable indicating whether or not a firm publicly disclosed their environmental performance	0.20	0.40	0.00	1.00
Growth	Log of annual change in sales ratio	-2.26	1.02	-16.12	2.33
Leverage	Log of total debt divided by total assets	-2.83	4.01	-16.12	1.41
Capital Intensity	Log of capital expenditures divided by total sales	-3.92	3.28	-16.12	8.55
Firm Size	Log of total assets	8.53	1.57	0.27	14.61

Table 3 Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Return on Assets	1.00																
2. Tobin's Q	0.38	1.00															
3. Total GHG	0.00	-0.39	1.00														
4. Direct GHG	-0.04	-0.38	0.92	1.00													
5. Supply Chain GHG	0.05	-0.35	0.95	0.77	1.00												
6. Water Abstraction	-0.06	-0.16	0.48	0.48	0.42	1.00											
7. General Waste	0.03	-0.29	0.75	0.65	0.78	0.20	1.00										
8. Volatile Organic Compounds	0.01	-0.25	0.71	0.66	0.72	0.45	0.57	1.00									
9. Heavy Metals	-0.04	-0.22	0.68	0.68	0.62	0.82	0.40	0.61	1.00								
10. Natural Resources	0.03	-0.09	0.17	0.29	0.07	0.21	0.04	0.04	0.18	1.00							
11. KLD Concerns	-0.03	-0.21	0.60	0.62	0.52	0.44	0.36	0.38	0.51	0.26	1.00						
12. KLD Strengths	0.03	-0.06	0.31	0.22	0.34	0.25	0.19	0.20	0.30	-0.05	0.28	1.00					
13. Disclosure	0.00	-0.14	0.46	0.50	0.34	0.36	0.19	0.17	0.40	0.47	0.43	0.36	1.00				
14. Growth	0.02	0.25	-0.23	-0.19	-0.22	-0.05	-0.20	-0.17	-0.11	0.04	-0.11	-0.11	-0.09	1.00			
15. Firm Size	-0.11	-0.37	0.74	0.62	0.75	0.17	0.61	0.49	0.36	0.07	0.42	0.29	0.38	-0.19	1.00		
16. Leverage	-0.22	-0.33	0.32	0.29	0.31	0.16	0.25	0.25	0.24	0.08	0.17	0.09	0.16	-0.12	0.30	1.00	
17. Capital Intensity	-0.12	0.00	0.01	0.15	-0.11	0.13	-0.15	-0.08	0.13	0.32	0.12	0.00	0.31	0.09	0.05	0.03	1.00

Table 4 Panel analysis GHG emissions on ROA

Dependent Variable	**ROA (t+1)**					
Method (Model)	*Fixed Effects (1)*	*Random Effects (2)*	*Fixed Effects (3a)*	*Random Effects (4)*	*Fixed Effects (3b)*	*Fixed Effects (3c)*
Total GHG Emissions	0.019 (0.009)*	0.019 (0.003)**				
Direct GHG Emissions			0.002 (0.005)	-0.002 (0.002)	0.005 (0.005)	
Supply Chain GHG Emissions			0.019 (0.010)*	0.026 (0.003)**		0.020 (0.010)*
Controls						
Water Abstraction	-0.001 (0.001)	-0.002 (0.000)**	-0.001 (0.001)	-0.002 (0.000)**	0.000 (0.001)	0.000 (0.001)
General Waste	0.001 (0.002)	0.003 (0.001)*	0.000 (0.002)	0.002 (0.002)	0.001 (0.003)	0.000 (0.003)
VOCs	0.001 (0.001)	0.000 (0.001)	0.000 (0.001)	-0.000 (0.001)	-0.003 (0.002)	-0.003 (0.002)
Heavy Metals	-0.001 (0.002)	-0.001 (0.001)	-0.002 (0.002)	-0.001 (0.001)	0.004 (0.003)	0.003 (0.003)
Natural Resources	0.001 (0.001)	0.001 (0.001)	0.000 (0.001)	0.001 (0.001)	0.002 (0.002)	0.002 (0.001)
KLD Concerns	0.002 (0.003)	-0.001 (0.002)	0.002 (0.003)	-0.001 (0.002)	0.000 (0.005)	0.001 (0.005)
KLD Strengths	0.001 (0.003)	0.004 (0.002)	0.001 (0.003)	0.002 (0.002)	0.000 (0.005)	0.000 (0.005)
Disclosure	0.001 (0.005)	0.004 (0.004)	0.002 (0.005)	0.006 (0.004)	0.005 (0.007)	0.003 (0.007)
Growth	0.007 (0.002)**	0.005 (0.002)**	0.007 (0.002)**	0.005 (0.002)**	0.007 (0.002)**	0.007 (0.002)**
Leverage	-0.001 (0.001)	-0.003 (0.000)**	-0.001 (0.001)	-0.003 (0.000)**	0.000 (0.001)	0.000 (0.001)
Capital Intensity	0.000 (0.002)	-0.001 (0.001)	0.001 (0.002)	-0.000 (0.001)	-0.003 (0.003)	-0.003 (0.003)
Firm Size	-0.047 (0.005)**	-0.028 (0.003)**	-0.047 (0.008)**	-0.031 (0.003)**	-0.040 (0.007)**	-0.047 (0.008)**
Industry dummy	No	Yes	No	Yes	No	No
n	3316	3316	3316	3316	3316	3316
Number of firms	1095	1095	1095	1095	1095	1095
Hausman[a]		37.61**		37.07**		

Table 5 Panel analysis of GHG emissions on Tobin's q

Dependent Variable	**Tobin's q (t+1)**					
Method (Model)	*Fixed Effects (5)*	*Random Effects (6)*	*Fixed Effects (7a)*	*Random Effects (8)*	*Fixed Effects (7b)*	*Fixed Effects (7c)*
Total GHG Emissions	-0.750 (0.107)**	-0.081 (0.045)				
Direct GHG Emissions			-0.097 (0.058)	-0.071 (0.029)*	-0.210 (0.001)**	
Supply Chain GHG Emissions			-0.762 (0.124)**	-0.021 (0.050)		-0.827 (0.000)**
Controls						
Water Abstraction	-0.007 (0.011)	-0.013 (0.008)	-0.007 (0.011)	-0.016 (0.008)	0.011 (0.012)	0.015 (0.0125)
General Waste	-0.007 (0.041)	0.018 (0.033)	-0.012 (0.032)	0.015 (0.033)	-0.084 (0.032)**	-0.043 (0.032)
VOCs	0.017 (0.017)	0.021 (0.015)	0.016 (0.017)	0.022 (0.015)	0.004 (0.017)	0.008 (0.017)
Heavy Metals	-0.019 (0.033)	0.030 (0.021)	-0.022 (0.033)	0.032 (0.021)	-0.034 (0.030)	0.006 (0.031)
Natural Resources	0.026 (0.016)	0.011 (0.010)	0.025 (0.016)	0.014 (0.010)	0.022 (0.016)	0.027 (0.016)
KLD Concerns	0.091 (0.055)	0.108 (0.039)**	0.078 (0.055)	0.111 (0.039)*	0.085 (0.054)	0.075 (0.053)
KLD Strengths	-0.098 (0.049)*	0.048 (0.041)	-0.099 (0.049)	0.041 (0.169)	-0.098 (0.049)	-0.094 (0.049)
Disclosure	-0.060 (0.082)	0.176 (0.071)*	-0.072 (0.082)	0.169 (0.071)*	-0.077 (0.0.081)	-0.008 (0.080)
Growth	0.045 (0.022)*	0.046 (0.020)*	0.046 (0.022)*	0.048 (0.021)*	0.042 (0.022)	0.046 (0.022)*
Leverage	-0.010 (0.009)	-0.033 (0.007)**	-0.010 (0.009)	-0.033 (0.007)**	-0.008 (0.009)	-0.010 (0.009)
Capital Intensity	-0.089 (0.059)	0.074 (0.032)*	-0.089 (0.059)	0.086 (0.032)**	0.013 (0.058)	-0.020 (0.057)
Firm Size	-0.568 (0.086)**	-0.351 (0.043)**	-0.513 (0.090)**	-0.375 (0.045)**	-0.783 (0.079)**	-0.520 (0.089)**
Industry dummy	No	Yes	No	Yes	No	No
n	2678	2678	2678	2678	2678	2678
Number of firms	880	880	880	880	880	880
Hausman[a]		82.00***		101.74***		

Figure 1 Histogram of observations (firm-years) by sector

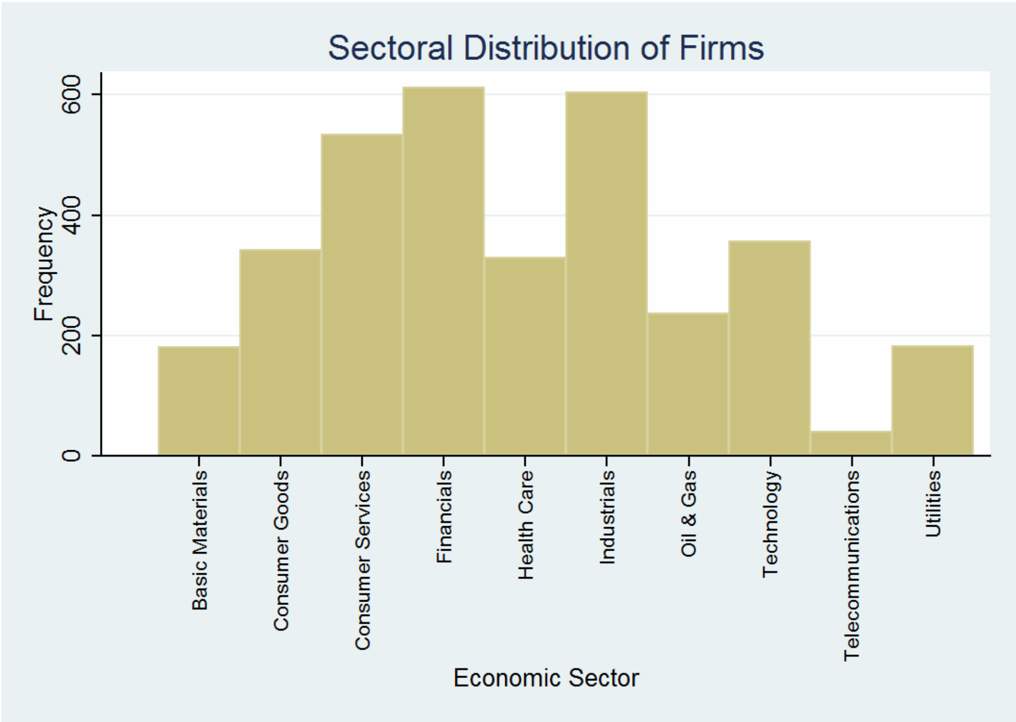

Figure 2 Mean greenhouse gas emissions (CO2-e) by sector