Show Me the Green: Three Essays on Information Systems Value and Environmental Performance in Global Organizations

by

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A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Business Administration)
in the University of Michigan
2015

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Lake Pend Oreille, ID
Photo by Mark G. Murray, my childhood hero

DEDICATION

To my family: past, present, and future.

ACKNOWLEDGMENTS

Too many people have provided material support to this effort for me to thank them all by name. Despite the clear danger that I will omit someone who made an absolutely vital contribution, I will nonetheless attempt a partial list.

First, I must thank my advisor, Nigel Melville for his patience, thoughtful reflection and keen insights throughout the process of writing this dissertation. I also thank my committee, Andrew Hoffman, Gautam Kaul and MS Krishnan, for their attention, insights and support. I would not have reached the dissertation stage without the engagement of many other Ross faculty, including Michael Gordon, Scott Moore, Hila Etzion, Gerald Davis, Amitabh Sinha, and Gautam Ahuja. I am indebted to the faculty of the then-BIT department who freely offered their comments and support in the early stages of my career: Thomas Schriber, Dennis Severence, Joe Walls, Jerry Peterson, Neil Nelson (and operations stalwart Eric Svaan). I am also appreciative for insights, opportunities and guidance from faculty outside Ross, including Kai Zheng, Charles Friedman, Julia Adler-Milstein, Ronald Ramirez and Kevin Kobelsky. The network of Michigan Ross BIT alumni has been an invaluable support and delight to get to know, for which I must thank Ajit Sharma, Suresh Malladi, Sanghee Lim, Terence Saldanha, Min-Seok Pang, Mark Madrilejo, Andrea Walrath, Sajeev Cherian, Ali Tafti, Ramnath Subramanyam, Narayan Ramasubbu, and Sunil Mithas.

Brian Jones, Kelsey Belzak and Roberta Perry of the Ross PhD office are simply indispensable and I am fortunate to have had my administrative life in their charge.

Similarly, my development as a teacher and writer was profoundly impacted by Karen Bird, Christine Feak and Brenda Imber.

I also thank audiences at the following conferences and workshops at which prior versions of this work were presented and refined: 2012 International Conference on Information Systems, 2013 ICOS Dissertation Symposium, 2014 Big 10 IS Symposium, 2014 Americas Conference on Information Systems, 2014 INFORMS annual meeting, and the 2014 Workshop on Information Technology and Systems. The financial support of the Ross School of Business, its TO and BIT departments, ISEF, the Stark Family, the U of M Office of Financial Aid, and the Horace Rackham Graduate School are gratefully acknowledged. Without this support I would not have been in graduate school pursuing my dream.

Few journeys are possible without fellow sojourners, and I wish to thank Genna Cohen and many other ICOS participants for involving me in their projects, camps and discussions and teaching me the benefits of collegiality. Similarly, members of the 2012-2014 PhD forums are gratefully acknowledged for helping me to practice service in the face of adversity. My R4431 office-mates are also thanked for their high-fives, support in difficulty and celebration, not to mention senses of humor. Moving beyond campus, I must thank many friends in Northwood, the men of Friday morning, and numerous coffee-shop, backgammon, and brewing conversation partners who refreshed and revived me throughout this journey. Lastly, this research would not have been possible without the support of my family. To my grandparents, cousins, parents and daughters – thank you for your encouragement, inspiration and love. To my wife – this journey would not have been possible without you. I love you.

To the almighty, my heavenly father, I thank you for the gift of creation, your presence in it, and the responsibility to care for it.

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ABSTRACT

Businesses utilize information systems (IS) to increase revenues, reduce costs, and spur innovation. IS automate tasks, generate and deliver information, and can transform core value creation processes. As climate change and its associated challenges become increasingly relevant to business enterprises worldwide, IS are a key tool in enabling their response. Prior research shows that IS can either aid or inhibit organizational efforts, yet we do not fully understand their influence in this important context. This dissertation presents three essays examining how IS affects financial market value and greenhouse gas emissions performance in large businesses.

The first essay (chapter 2) introduces a method utilized in chapter 3. After finding a surprising dearth of international event studies in the IS discipline, a multiple-factor method is selected from related management literature to estimate international financial market reaction. Its performance relative to the commonly-used single-factor model is evaluated with a Monte Carlo analysis. Error correction improvement of the multiple factor model is calculated to be 44%-99% over the single-factor model for conditions observed in world markets 2000-2012.

The second essay (chapter 3) utilizes the multiple-factor model from chapter 2 to investigate international financial market reaction to Carbon Management Systems (CMS) adoption. CMS, a class of IS, enable the capture and management of carbon footprints. Three main results emerge. First, shareholders do not react positively to CMS announcements, as wealth effects are either not significant or negative, depending on the

specification. Second, markets appear to penalize firms in more carbon regulated countries versus others, consistent with theory. Lastly, negative reactions to CMS appear to be dampening over time.

The third essay (Chapter 4) examines the impact of IS on firm GHG emissions for large corporations with a presence in North America. This first-of-its-kind analysis finds interaction effects between GHG reduction plans and the physical deployment scope of ERP modules for Enterprise Support (e.g. HR, Finance, Accounting). Corporations with reduction plans in place and the highest 18% of ES physical scope are associated with reduced CO2 emissions. A one-standard-deviation increase in the ES physical scope deployment measure reduces GHG emissions by 46.63% for these companies.

Chapter 1 Introduction and Motivation

> *"Human influence on the climate system is clear . . . continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions."* – Intergovernmental Panel on Climate Change (2013)

Information systems connect humanity across the globe in an unprecedented fashion. These systems have been harnessed by advocates of social change and governments seeking to fulfill their mandates. No less radical are the changes wrought by businesses in transforming their value-creation processes using technology-mediated systems for information, automation and control. While businesses have long utilized information systems to increase revenues, reduce costs, drive efficiency, and spur innovation, increasingly salient challenges in the natural environment present a new domain for businesses to apply their technological acumen. This dissertation focuses on information systems within large profit-making organizations and how those systems can affect organizational performance as reflected in financial market value and greenhouse gas emissions.

Organization leaders are increasingly responding to changes in their business environment that originate from challenges in the natural environment. A significant challenge with global reach and long-term impacts is climate change resulting from anthropogenic greenhouse gas (GHG) emissions (IPCC, 2013). Organizations experience the effects of climate change in a number of ways. For instance, the bottom lines of some organizations are directly impacted, such as those in the reinsurance industry as it adjusts to more frequent extreme weather events. Businesses in some jurisdictions face increased regulation from governments committed to reducing GHG emissions. Yet other organizations are under pressure from their stakeholders as customers, suppliers, shareholders, and political groups urge them to respond to climate change by reporting their GHG emissions, adopting organizational GHG goals, or certifying the embedded GHG emissions in products. To take action, though, organizations must be equipped with the data and tools necessary to measure, monitor, and manage their GHG output. It is this need for data and tools that information systems (IS) for environmental sustainability can fill.

Definitions and Positioning

The work in this dissertation stands at the intersection of IS business value and corporate environmental performance literatures (see Figure 1). "Sustainability" is a highly contextual and ambiguous term, though it can be viewed broadly as integrating environmental thinking into social, political, and economic activity (Elkington, 1994). Research on the environmental sustainability of business has proceeded in waves over the last 40 years focusing first on regulation, then strategic environmentalism, and now globalization, which includes climate-related and IT research (Hoffman & Bansal, 2012).

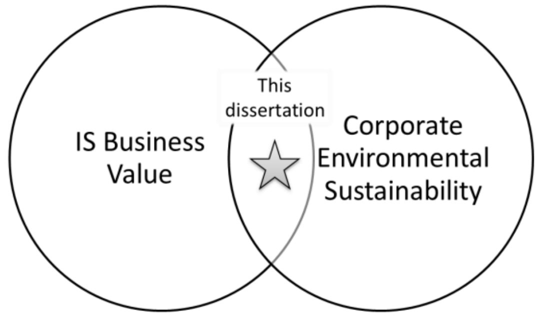

Figure 1. Placement in Literature

Several conceptual and theoretical paradigms have been employed in this research, including the shared value approach (Porter & Kramer, 2006), agency theory and a neo-institutional perspective (Ioannou & Serafeim, forthcoming), the resource based view (RBV) (Surroca, Tribó, & Waddock, 2010), and Hart's (1995) Natural Resource Based View (NRBV). Hart's (1995) NRBV view posits that pollution prevention, product stewardship, and sustainable development lead to superior performance (competitive advantage). By adopting relevant paradigms from the above sources, this dissertation seeks to contribute to our understanding of sustainability by investigating information systems, their use for carbon management, and their impact on environmental performance. This dissertation is thus about the *environmental sustainability of IS,* which is defined as *the application and operation of IS to minimize the negative impacts and maximize the positive impacts of organizational behavior on the environment* (adapted from Elliot, (2011)).

Often known as "Green IS", the development and use of information systems for environmental sustainability can impact an organization's environmental footprint both directly (e.g. by mitigating emissions through dematerialization) and indirectly (e.g. by supporting sustainability initiatives and efficiency gains). This is distinct from "Green IT" (though "Green IS" encompasses this term as well), which typically refers to efforts to reduce resource consumption and life-cycle waste products that are generated by IT hardware (Jenkin, Webster, & McShane, 2011; Loeser, 2013; Watson, Boudreau, & Chen, 2010). It is the underlying argument of this dissertation that information systems deployed by organizations are essential to gathering data about and actively managing GHG emissions. These systems, when combined with organizations' managerial and technical capabilities and deployed into the organization's particular context, contribute to their ultimate degree of success in environmental outcomes and recognition by financial markets. A specific example of IS to measure, monitor, and manage GHG emissions that are directly investigated in Chapter 3 of this dissertation are Carbon Management Systems (CMS). These systems have only just begun to be studied in the IS community and are defined as complex software systems that receive various environmental data inputs, process them into usable information such as greenhouse gas scopes, and then provide enhanced functionality, such as automated reporting or workflow (Corbett, 2013; Melville & Whisnant, 2014).

Research Questions

This dissertation consequently asks the questions: *"What are the financial market impacts of IS for carbon management?"* and *"What are the environmental impacts associated with enterprise IS in general?"* These are important and relevant for three reasons: (1) IS in general and CMS in particular represent important tools in enabling society to respond to the environmental threat of climate change, (2) Despite this potential, there is much we do not know about the effects of a GHG-focused IS, including the fundamental questions of how they are perceived in the financial markets, what are their environmental impacts, and to whom do benefits and/or costs accrue?

(3) Information systems can either aid or inhibit organizational responses, making them an important mediator to performance, yet we do not fully understand their influence in this important context. To the best of my knowledge, this dissertation is among the first works that investigate the business performance outcomes of CMS and one of the first that examines IS for GHG emissions management at the organizational level.

Contents and Contributions

Following this introduction, chapter 2 presents an essay on methodology examining the classic short-window event study used in IS, accounting, finance, strategy, management and the corporate environmental sustainability literatures (among others). Given the innovative nature of CMS studied in chapter 3, the event study was selected as an appropriate method to provide a leading financial indicator of value based on investor reaction to this new type of technology. These systems are being adopted worldwide under differing regulations and business climates, indicating the need for an international event study. However, conducting a literature review on event studies in international settings found only minimal methodological guidance and raised important questions. This study's first contribution is identifying the dearth of international event studies in the IS discipline, despite the increasingly global nature of modern information systems utilized by businesses (e.g. outsourcing and cloud computing). While calling for this gap to be filled, this chapter also seeks to make scholars aware of research findings that single-factor event study methods developed for single-country settings may result in estimation errors if not corrected for international use (Park, 2004).

To evaluate the extent of this bias, this chapter conducts a Monte Carlo analysis to simulate security returns within the context of varying (a) levels of global stock-market correlation and (b) structural relationships between securities and their markets. Evaluating the performance of the single-factor and international multi-factor methods, leads to this study's second contribution: calculating the amount of error correction that would result from using Park's multiple-factor market model instead of a single-factor market model event study method in international event studies. An examination of the world's financial markets since 2000 shows that they have been in the range where the multiple factor model exhibits some of its largest error correction (44%–99% improvement), implying that the multiple factor model should be used when conducting international short-window event studies. The results of this work may be of relevance and interest to researchers in multiple disciplines.

Building on the method discussed in the prior chapter, the essay presented in chapter 3 quantifies financial market reaction for Carbon Management Systems (CMS). CMS are an emerging class of information system being adopted by companies responding to business logics and external pressures to measure and manage their greenhouse gas emissions. The roles of important contextual factors such as regulation are evaluated and three main results emerge. First, shareholders do not appear to react positively to CMS announcements, as shareholder wealth effects are either not significant or negative, depending on the specification. The second finding sheds further light on these results by illustrating that markets appear to penalize firms in more carbon-regulated countries versus others, possibly suggesting market expectations for negative returns under these conditions, or perhaps penalizing management for not having proactively adopted CMS prior to regulation. Lastly, I find that negative reactions to CMS appear to be dampening over time, consistent with literature theorizing a shift in the institutional logics of financial markets.

The final essay in chapter 4 expands the performance outcome of information systems to impacts on the natural environment by investigating the influence of certain enterprise information systems on organizational greenhouse gas emissions for large corporations with a presence in North America. This expansion answers a call from senior scholars who have called for IS researchers to study new business value outcome measures beyond traditional productivity, process and financial measures (Kohli & Grover, 2008). The study's primary contribution is that its preliminary analysis finds interaction effects between GHG reduction plans and the scope of physical deployment of ERP modules for Enterprise Support (e.g. HR, Finance, Accounting). Corporations with the highest 18% of ES physical scope are associated with reduced CO_2 emissions, with a one-standard-deviation increase in the ES physical scope deployment measure reducing GHG emissions by 46.63%. Though an important foundation has been laid, these results are subject to several limitations which are discussed and future research is proposed to address them.

Chapter 5 concludes the dissertation with a summary, future research directions, and final thoughts.

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Chapter 2 IT and Market Value in a Global Context: A Monte Carlo Investigation Informing International Event Studies

Introduction

Information technology (IT) spending exceeds $3 trillion USD in 2014[1] and represents the largest category of capital expenditures in some countries (Ranganathan & Brown, 2006). Given such substantial sums, business executives, software developers, and policy makers demand to know the value realized from such spending, and if the solutions purchased are worth their cost.

A rich and varied literature on the business value of IT has developed to answer this question, and researchers with training in stock markets and accounting performance measures have performed many market-level analyses of systems and technology (Dehning & Richardson, 2002; Konchitchki & O'Leary, 2011; Masli, Richardson, Sanchez, & Smith, 2011). Definitions of value and worth vary in this literature, with researchers investigating both monetary measures of business value (e.g. capitalized book value of the investment, additional revenues driven by the investment, money saved through increased efficiencies) and non-monetary measures (e.g. innovation, strategic opportunities enabled, market share gained). Another measure of value that is of particular interest to policy makers when they consider requiring or incentivizing a particular IT investment is the non-monetary value to consumers and society. This goes

[1] http://www.gartner.com/newsroom/id/2643919

beyond economic notions of consumer surplus. For example, electronic health records are expected to reduce medical errors and increase the quality and continuity of care, and environmental management systems increase health and human safety by enabling the reduction of harmful emissions.

While the challenges in estimating societal and other non-monetary value are many, even measuring monetary value for a particular type of investment can present challenges, be subject to estimation errors, and suffer from lack of data. For instance, while one company's IT expenditures and their impact on later revenues or expenses may be imputed from annual statements, extending this estimate to a large number of companies is time-consuming and other sources of IT spending are scarce and subject to sample selection limitations (Dehning and Richardson 2002). The problem of gathering IT investment impacts is further compounded when comparing firm decisions across countries that may have different accounting standards and financial reporting requirements. Resolving inconsistencies requires subjective judgments on how to make book measures comparable and how to extrapolate IT's influence from those varying measures. Even if all the relevant data could be gathered and made comparable, estimating costs and benefits via annual statements is also subject to the limitation that it is ex-post. This makes financial report measures of performance particularly ill-suited to estimate the monetary value of newer classes of emerging technologies which may be in the initial stages of adoption.

One solution to overcome many of these problems is the short-window event study, which captures a measure that is forward-looking, quantifiable, and utilizes widely available data to calculate the market valuation changes following an IT adoption announcement. First proposed by accounting and finance researchers (Ball & Brown, 1968; Fama, Fisher, Jensen, & Roll, 1969), the event study has proven to be widely adopted and frequently used tool for investigating the financial impact of corporate actions through examining stock market reactions to those actions. The method is widely used in fields such as macroeconomics, finance, accounting, and management (Fama, 1991; Konchitchki & O'Leary, 2011) and has yielded a number of useful insights for the information systems (IS) field.

Findings include that innovative and infrastructure IT investments result in greater shareholder wealth than non-innovative and application IT investments (Chatterjee, Pacini, & Sambamurthy, 2002; Dos Santos, Peffers, & Mauer, 1993); the value of enterprise resource planning (ERP) investments are contingent on contextual factors such as company size, health, and the functional and physical scope of the modules being implemented (Hayes, Hunton, & Reck, 2001; Ranganathan & Brown, 2006); and e-commerce announcement gains are larger for business-to-consumer and tangible goods than they were for business-to-business and digital goods (Subramani & Walden, 2001).

Surprisingly, despite the event study's use and acceptance, few IS event studies appear to span international boundaries (Roztocki & Weistroffer, 2011). This is in contrast to the rapid increase in international event studies in related management disciplines such as accounting and finance, where international event studies are considered an important tool to study the impact of factors that are relatively constant within a country, but can vary widely between countries (Campbell, Cowan, & Salotti, 2010a; DeFond, Hung, & Trezevant, 2007). As advances in communications, digitally-enabled global commerce and computing transforms markets, supply chains and organizational decision making, understanding the effects of these changes in an international context is increasingly important to decision makers within companies, foundations and governments.

Fortunately, world-wide stock returns data are increasingly available (e.g. via DataStream), allowing differences in international stock market reactions to IS adoption and other events to be examined to gain insights into topics such as the impact of differing tax treatments on decisions to invest in particular types of IS, the influence of country-specific labor force training and attitudes on IT adoption or abandonment, or perhaps the financial cost of country-specific differences in managing data and processes (Wang, Klein, & Jiang, 2006). In this paper we advocate for an increased use of the international event study in IS literature, develop empirical evidence to potentially enhance the robustness of international event studies, and thereby support further integration and collaboration among accounting information systems (AIS), accounting, and IS research streams so that they can cross-pollinate and suggest future research directions for each other's efforts (Debreceny, 2011).

To these ends, we ask the following two research questions:

RQ 1: *In light of the global economy, to what extent do existing IS event studies span international boundaries, and if they don't, how is that scope limitation rationalized?*

RQ 2: *When conducting an international event study, under what conditions should methodological adjustments (if any) be made to enhance robustness of estimates (i.e. reduce bias)?*

To answer the first question, we start with a brief history of the event study, highlight selected contributions to IS research, and draw from two recent systematic literature reviews of the method's use in IS. We then develop and conduct extensive simulation experiments to examine the second question. We do this by employing data constructed to model an international financial market setting and using two different methods of estimating the market reaction to an event. The first is the conventional approach used for single-country studies, while the second is an advanced model developed to address issues arising in global event studies. Regarding the latter, while various multiple-factor models have been proposed as extensions to the traditional single-factor event study model (e.g. Fama French), we test the market model extension developed by Park (2004) given its explicit international affordances and robust theoretical basis. We also do not address all challenges in conducting international event studies, but rather focus on the issue of bias in market value estimates.

To emphasize, the contribution following from our second research question has not been examined in prior research: the use of Monte Carlo simulation to identify market conditions under which bias is most likely to occur with the conventional event study estimation method and evaluation of the efficacy of a employing a multi-factor extension.

By understanding the potential for bias when applying single-country methods to multiple country settings and how to avoid it, AIS, IS and other researchers will be equipped to provide more accurate estimates of the market value effects of international IS events. This has two advantages: first it encourages researchers to conduct IT comparisons across international boundaries that are sorely lacking in the literature to date. Secondly, it allows those comparisons to yield more accurate answers to questions about the business value of information systems, lessening the danger of arriving at the wrong conclusion about an IS investment's financial impact. Overall, our results indicate that for conditions often observed in global markets, the conventional single-factor model produces biased estimates for which the multi-factor model is able to provide substantial correction.

A Brief Literature Review of the Event Study and its Use in IS

Initially conceived of as a test of financial market efficiency (Fama et al., 1969), the event study method has been widely adopted in the intervening 40+ years. This method is based on the assumption of a "relatively efficient capital market" (Dos Santos et al., 1993) which states that upon receiving news, the market rapidly incorporates that news into the stock price of a firm, changing the price to reflect the benefit the investment is expected to contribute to the firm's net present value (NPV) of future cash flows. While various formulations exist (see Corbett, Montes-Sancho and Kirsch (Corbett, Montes-Sancho, & Kirsch, 2005) for a non-typical example), one of the most common involves examining daily financial market returns surrounding an event of interest to determine its market value effects driven by an increase or decrease in share price (McWilliams & Siegel, 1997).

These market value effects have been studied in the IS literature and used to quantify the financial return of IT investments (Chatterjee et al., 2002; Dehning, Richardson, & Zmud, 2003; Dos Santos et al., 1993; Im, Dow, & Grover, 2001; Masli et al., 2011). They have also been used to examine the value of the CIO position (Chatterjee, Richardson, & Zmud, 2001; Khallaf & Skantz, 2007), e-commerce announcements (Dehning, Richardson, Urbaczewski, & Wells, 2004; Subramani &

Walden, 2001), IT outsourcing decisions (Agrawal, Kishore, & Rao, 2006), ERP implementations (Hayes et al., 2001; Ranganathan & Brown, 2006) and IT standards setting (Aggarwal, Dai, & Walden, 2011). Novel extensions and applications of the event study method have also appeared within the IS literature, for example through the inclusion of an adjustment for risk (Dewan & Ren, 2007). More recently, an examination of changing macroeconomic conditions on groups of companies demonstrated that despite the prevalence of IT, some industries still have opportunities for IT investments to increase productivity (Dos Santos, Zheng, Mookerjee, & Chen, 2012).

A small number of IS studies have also ventured into the international setting, including an investigation of the addition of an internet channel by European newspapers across four countries (Geyskens, Gielens, & Dekimpe, 2002) and a study of market reaction to IT investments comparing China to the US (Meng & Lee, 2007). These are the exception, as shown by two recent systematic reviews of the event study in the IS (and AIS) literature which found that most IS studies limit their scope to the US (Konchitchki & O'Leary, 2011; Roztocki & Weistroffer, 2011). For instance, of the 52 IS event studies reviewed by Konchitchki & O'Leary (2011), only two search explicitly international news sources. Roztocki & Weistroffer (2011) devote a brief section to geographic scope, noting that of the 73 studies they examined, 69 are limited to a single country, of which 64 are limited to the US. Table 1 presents a sampling of these papers, along with their discussion of why the study is limited to the US. Most often, there is little to no discussion of the rationale for the limitation, and if the limitation is discussed, it is most commonly a simple statement that the study was limited to US exchanges or a data source that contains only US data (typically the Center for Research in Security

Prices (CRSP)). Given the limited scope, these studies fail to provide estimates of value for global phenomena, missing an opportunity to gain broader insights by comparing the influence of factors that vary between countries on those phenomena.

Table 1. Information Systems Event Studies and Rationale for US Setting

Article	**Title**	**Rationale**
Dos Santos, Peffers and Mauer (1993)	The Impact of Information Technology Investment Announcements on the Market Value of the Firm	No discussion
Hayes, Hunton and Reck (2001)	Market Reaction to ERP Implementation Announcements	No discussion
Im, Dow and Grover (2001)	A Reexamination of IT Investment and the Market Value of the Firm—An Event Study Methodology	Replication / Extension
Subramani and Walden (2001)	The impact of e-commerce announcements on the market value of firms	No discussion
Chatterjee, Richardson and Zmud (2001)	Examining the Shareholder Wealth Effects of Announcements of Newly Created CIO Positions	No discussion
Chatterjee, Pacini and Sambamurthy (2002)	The shareholder-wealth and trading-volume effects of information-technology infrastructure investments	No discussion
Geyskens, Gielens, and Dekimpe (2002)	The Market Valuation of Internet Channel Additions	International Setting
Dehning, Richardson and Zmud (2003)	The Value Relevance of Announcements of Transformational Information Technology Investments	Prior research
Dehning, Richardson, Urbaczewski and Wells (2004)	Reexamining the value relevance of e-commerce initiatives	Replication / Extension
Agarwal, Kishore and Rao (2006)	Market reactions to E-business outsourcing announcements: An event study	No discussion
Ranganathan and Brown (2006)	ERP Investments and the Market Value of Firms	No discussion
Meng and Lee (2007)	The value of IT to firms in a developing country in the catch-up process: An empirical comparison of China and the United States	International Setting
Dewan and Ren (2007)	Risk and return of information technology initiatives: Evidence from electronic commerce announcements	Replication
Khallaf and Skantz (2007)	The Effects of Information Technology Expertise on the Market Value of a Firm	No discussion
Song, Woo and Rao (2007)	Interorganizational information sharing in the airline industry: An analysis of stock market responses to code-sharing agreements	Stock data of foreign firms not available (1984-1997)
Goldstein, Chernobai, and Benaroch (2011)	An Event Study Analysis of the Economic Impact of IT Operational Risk and its Subcategories	No discussion

Article	Title	Rationale
Aggarwal, Dai and Walden (2011)	The more, the merrier? How the number of partners in a standard-setting initiative affects shareholder's risk and return	Follows prior studies
Dos Santos, Zheng, Mookerjee, and Chen (2012)	Are New IT-Enabled Investment Opportunities Diminishing for Firms?	No discussion

Note: All studies limited to the U.S. except Geyskens et al. (2002) and Meng and Lee (2007).

Overview of Event Study Estimation Methodology

Event studies estimate the change in market value associated with a specific event to quantify the discounted return that financial markets project a company will earn from the studied action. To gain a true measure of this change, it is insufficient to simply observe the realized return following the event; it is also necessary to estimate what the return would have been without the event. The difference between the estimated counterfactual and the observed return is referred to as the abnormal return and is attributed to the event being studied. We focus on the short-window event study in this paper. Readers unfamiliar with the event study are directed to a more comprehensive description of the conventional single-factor market model method found in McWilliams and Siegel (1997), or a more recent discussion that can be found in Konchitchki and O'Leary (2011).

Single Factor (Market) Model

To estimate an abnormal return using the single factor market model, researchers first calculate coefficients that describe the relationship between a firm's stock returns and measure of market returns (e.g. CRSP Equally-weighted index, or the S&P 500). This is done by using OLS to regress the daily returns for firm i on the daily market returns over an estimation period, which is typically a period of substantial length (e.g.

200 trading days), prior to the event and often separated from it by a buffer (e.g. 30 days). An estimation of "normal" returns (what the stock would have done if the event had not occurred) are then calculated as R_{it}^* in the equation:

$$R_{it}^* = \alpha_i + \beta_i R_{mt} \qquad (1A)$$

where α_i is the Intercept term from the OLS regression over the estimation period, β_i is the systematic risk of i-th firm, and R_{mt} is the actual return of the market for time period t ('normal returns' also include an error term ϵ_{it} with an expected value = 0 that the estimate R_{it}^* does not have). The Abnormal Returns (AR) for firm i in time period t are then calculated using the equation:

$$AR_{it} = R_{it} - R_{it}^* \qquad (2)$$

where AR_{it} is the abnormal return of i-th firm for time period t, R_{it} is the actual return of i-th firm for time period t and R_{it}^* is the estimated normal return for i-th firm for time period t. After the abnormal returns have been calculated, they are summed for each event window (a period of 1 or more days on which the event's impact is expected to occur), yielding the cumulative abnormal return (CAR) for firm i in that window. For the window that ranges from one day before the event to one day after it (3 days total), this would be given by equation: $CAR_i = \sum_{t=-1}^{t=1} AR_{it}$ (3)

These cumulative average returns are then aggregated across firms and divided by the number of firms in the group to calculate the mean cumulative abnormal return (MCAR) for the group[2].

To avoid bias when comparing events across countries, Park (2004) recommends constructing the counterfactual to the observed return using a multi-factor (world market) model instead of a single-factor (market) model. The determination of a counterfactual estimate using both models is presented in brief in the next section.

Challenges in Multi-Country Event Studies

Our examination of the literature to identify challenges in multi-country event studies revealed a variety of data and modeling issues, as well as recommendations to overcome them (Table 2). For example, it is important to correctly select and interpret inference tests (Campbell et al., 2010a). It is also important to appropriately use and clean international returns data (Ince & Porter, 2006). Given the wide scope of these findings, we focused on a single yet critically important issues: bias in market value estimates.

Multiple-Factor (World Market) Model

The world market model proposed by Park (2004) uses a different formulation of equation 1, given by $R^*_{ijt} = \alpha_i + \beta_i R_{mjt} + \gamma_i R_{wmt} + \delta_i X_{jt} + \epsilon_{ijt}$ (1B)

where α_i is the Intercept term, β_i is the systematic risk of i-th firm, R_{mjt} is the actual return of market j for time period t, R_{wmt} is the actual return of the world market (e.g. the

[2] Some researchers choose to standardize the CARs, calculating SCARs prior to summing and calculating the MCAR.

Financial Times and Stock Exchange (FTSE) All World Index, adjusted to subtract the influence of R_{mt}) for time period t, X_{jt} is the change in foreign currency exchange rates in country j on day t and ϵ_{ijt} is the error term with $E(\epsilon_{ijt}) = 0$. All other procedures remain the same.

Table 2. International Event Study Challenges and Corrections in the Literature

Challenge	Recommendation	Source
Selecting news sources for internationally-relevant events	Utilize news sources from multiple countries, such as the *Dow Jones* newswire, the *Bloomberg* news, or the *LexisNexis* database	(Park, 2004, p. 658)
Lack of synchronization between trading hours	Lag stock and local market return data by 1 day for firms from Asia or Australia/Oceania	(Park, 2004, p. 661)
Differences in institutional environments between countries (event selection)	Conduct interviews with experts about the selected countries, and/or conduct a pilot study to determine the appropriateness and applicability of the event of interest in the context of the studied countries.	(Park, 2004, p. 657)
Differences in institutional environments between countries (effect size calculation)	Exclude firms from the sample on the day of confounding events, which are more likely in international settings	(Park, 2004, p. 661)
Non-normal distributions for exchanges outside the US may cause inference mistakes when relying on the parametric tests such as the Patell test or the Standardized cross-sectional test	Rely on the Generalized sign test or the Rank test, both of which are well-specified and powerful under international conditions.	(Campbell, Cowan, & Salotti, 2010b, p. 3089)
Many international markets may have high frequencies of missing returns due to non-trading	Utilize the “trade to trade” method of omitting missing-price days from calculations while accounting for the corresponding market-index returns when the stock eventually does trade. This is superior to the “lumped returns” procedure where missing returns are treated as zero.	(Campbell et al., 2010b, p. 3079)

Challenge	Recommendation	Source
Thompson DataStream (TD), a common source for international stock market information exhibits the following challenging features, for which Ince and Porter (2006) recommend:		
TD repeats last known data for delisted firms	Remove delisted firms or delete all monthly observations from the end of the sample period to the first non-zero return	(Ince & Porter, 2006, p. 465)
TD Rounds prices to nearest penny prior to decimalization	Remove Penny stocks (drop observations with prices <1.00)	(Ince & Porter, 2006, p. 473)
TD Contains rounding and sometimes other errors in its return indices	Calculate returns directly from prices (and dividend data) instead of from return index	(Ince & Porter, 2006, p. 473)

Additional Analyses

Before describing the experiment to compare the two models, a note about how the estimates of CAR and MCAR are used. While the first output of an event study is an MCAR that describes the average effect of an event across all companies, we know from prior research that the effect of IT announcements differ with several contextual factors, including firm size, financial health, timing effects, and industry (Chatterjee et al., 2002; Dehning & Richardson, 2002; Im et al., 2001; Ranganathan & Brown, 2006). While earlier event studies split samples into groups and compared the sub-sample MCAR (e.g. Dos Santos, et al. (1993)), more recent analyses specify a regression with each company's CAR as the dependent variable and the factors that are either controlled for or under investigation as the explanatory variables (Khallaf & Skantz, 2007; Ranganathan & Brown, 2006). The experiment proposed next does not alter these additional analyses in any way but rather contributes to ensuring that each firm's CAR that these analyses rely on is accurately estimated.

Description of Experimental Setup

Data Generating Process and Simulation Plan

As Park (2004) notes, bias is likely to result if a single-country market model is applied to a multiple-country setting. Our experiment is designed to investigate the presence and size of this bias under a variety of conditions, focusing on (1) Integration: how integrated (correlated) world markets are with each other, and (2) Coupling: how loosely or tightly security prices are coupled with their local markets (measured by the beta coefficient used in the data generating process). This is achieved by creating a universe of security prices in which the world markets are integrated to varying degrees and the security prices are coupled more or less tightly to those markets via a data-generating-process (summarized in the first half of Table 3) that closely follows either the single-factor model (equation 1A) or the multiple factor model (equation 1B). We then estimate the size of the abnormal returns with both the single-factor and multiple-factor estimation models in each simulated condition to detect any systematic biases.

Table 3. Data Generating Process and Simulation Plan

Data Generating Process	
1	Securities: Generate 10,000 time series (length 276) via geometric Brownian motion. Risk-free rate and drift based on security characteristics observed in a sample of international pilot data[3]
2	Convert the security prices into daily returns and split into two 'markets' of 5,000 securities each
3	Foreign exchange rate (X_{jt}): Generate a time series according to a random draw from a normal population with a σ based on exchange rates between USD and other currencies in the pilot data
4	Market indices: Generate two time series using geometric Brownian motion with the same risk-free rate as the securities, but a drift based on market index characteristics observed in the pilot data
5	Transform the market index time series by inducing correlation between the two markets

[3] To gather realistic reference values for data generation, returns data for internationally listed stocks, market indices and foreign exchange rates from DataStream for the time period 2000-2012 were obtained and examined.

	at nine different levels (.1 to .9) and save the two indices at each of the 9 levels as possible states of nature
6	Construct a world market index from the daily mean of the two local market indices. Then calculate and store a version of the world market index for each local market that removes that local market's influence from the world market index (to avoid overweighting the local market's influence). In the two market setup described in this paper, the world market (less the local market's influence) is essentially the other local market index.
7	Construct 81 sets of 10,000 security returns for the 'Single-Factor' universe according to the equation $R_{it} = (1 - \beta_i)R_{it}^{ind.} + \beta_i R_{mt}$ that is derived from the single-factor estimation (1A) where $R_{it}^{ind.}$ is the independent portion of security i's return at time t (as calculated in step 2), and R_{mt} is the return of the local market index m at time t. Each of the 81 sets represents a unique combination of integration between the local market R_{mt} and the omitted world market (defined as a correlation of .1 to .9 and constructed in step 5) and a level of coupling (defined as linear dependence of each security on its local market index, set by β=.1 to .9).
8	Construct another 81 sets of security returns for the 'Multiple-factor' universe derived from Park's proposed extension to the event study estimation equation and given by $R_{it} = (\kappa - \beta_i)R_{it}^{ind.} + \beta_i R_{mt} + \gamma_i R_{wmt} + \delta_i X_{jt}$ where β, $R_{it}^{ind.}$ and R_{mt} are as above, R_{wmt} is the actual return of the world market (after subtracting the influence of R_{mt}) for time period t, X_{jt} is the change in foreign currency exchange rates in country j on day t, and γ_i and δ_i are fixed[4] and κ is a plug figure to ensure $\beta + \gamma + \delta + \kappa = 1$. Note that $X_{jt} = 0$ in market 1.
Simulation Plan	
1	Draw, at random and without replacement, 100 of the 10,000 securities from each set with the draw constructed so that the same securities are drawn from each of the 162 sets to allow for comparison.
2	Induce an event of the desired size (10%) on the same day for every security in the sample
3	For all 100 securities in the sample of all 162 sets (which represent specific levels of coupling and market integration as described in data generating process step 7), calculate the abnormal returns using both the traditional single-factor event study method (1A) and the multi-factor method (1B) and store the results.

[4] Values for γ_i and δ_i were fixed at values .07 and .03 for simplicity. Systematically varying them represents an opportunity for future research.

Results and Discussion

Simulation is useful because it allows the underlying structure of data to be known, permitting an evaluation of estimation methods applied to that data. Our results show that the multiple-factor world market model performs substantially better than the single-factor market model for many levels of world-market integration and coupling between stocks and their indices. This error improvement is graphically represented in Figure 2. Examining the error between the induced event size (which is set ex-ante) and the event size detected ex-post by each model shows that for levels of market integration ranging from .5 to .7, the multi-factor model exhibits much better error correction (44%-99% improvement[5]) than the single-factor model for all levels of security/market coupling except for those securities least coupled with the market (with β=.1). The results presented here are consistent with several robustness checks, including taking additional draws from the first generation of 1,620,000 securities as well creating and drawing from another iteration of generated securities.

[5] Improvement is calculated as $(|e1| - |e2|)/|e1|$ where e1 is the % error in the single-factor model and e2 is the % error in the multi-factor model. E.g. When e1 = -0.1249 and e2 = .0321, e2 is .0928 closer to 0 error, representing a 74.3% improvement over e1. The range of absolute differences between e1 and e2 is .0065 to .16 in the single-factor universe and -.0117 and .1535 in the multi-factor universe.

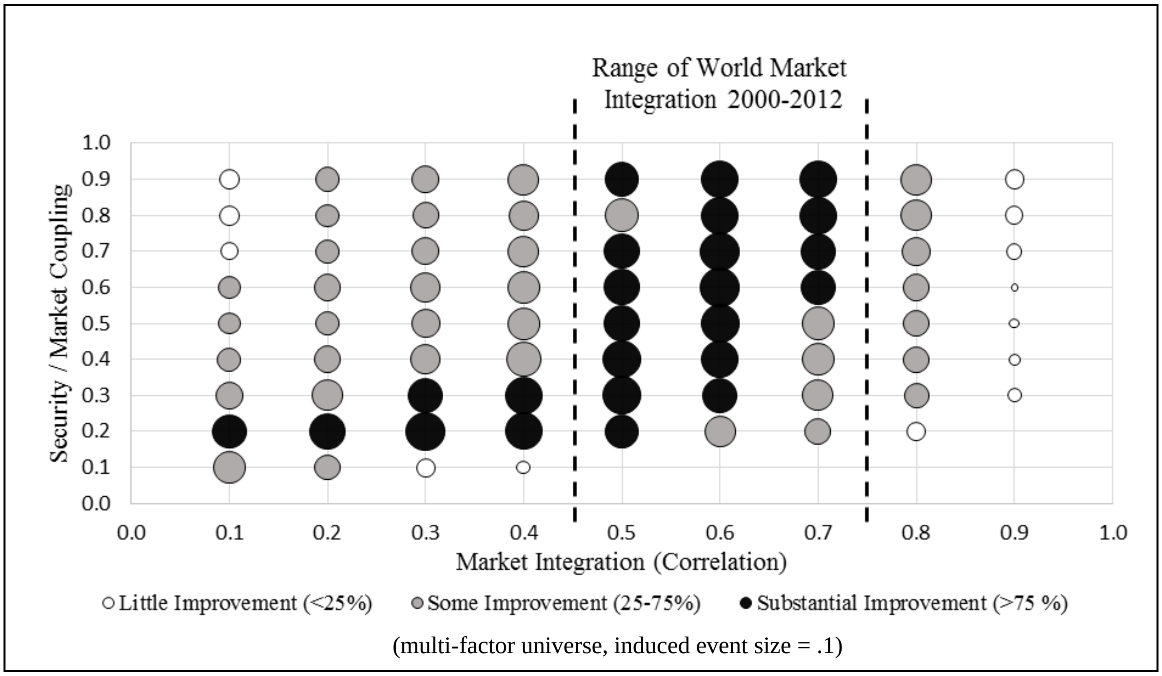

Figure 2. Multi-Factor Model Median Error Improvement over Single-Factor Model

This finding suggests that depending on the level of global market integration and security/market coupling that exists in actual financial markets, the use of the single-factor model in an international setting may introduce a strong negative bias and result in the financial impacts of announcements being substantially understated.

To highlight potential occurrences of problematic estimates from the single-factor model for which the multi-factor model demonstrates substantial correction, we next examine the actual correlations between daily stock market returns for various countries as represented by a leading large-capitalization stock market index for each.[6] Consider, for example, a hypothetical international event study with events spanning the years

[6] While many U.S. event studies choose to use equally-weighted indices, such indices are not readily available in many international markets. Thus, for consistency, market-capitalization (value) weighted indices that represent 70%-90% of their respective market are used for each country in this comparison.

2000-2012. In this example study, IS announcements were collected from 10 countries with company and index returns obtained from DataStream. To closely mirror the two-country setup of the simulation results, let's imagine the researcher is initially interested in comparing only a single country to the rest of the world. For the full 13 years, correlations between individual country indices and the world market index range from .486 to .787 (See Table 4), with 5 of the 10 countries in the "Medium" range (between .4 and .7) that can benefit most from the multi-factor model. These ranges of market integration are indicated on Figure 2. The "High" integration countries (above .7) will still likely benefit from reduced bias by using the multi-factor model, but not as much as the "Medium" integration countries. Splitting the 13 year span of the study into three time-periods yields 30 country/time-periods, over half of which are classified as Medium integration and able to greatly benefit from the multi-factor model. Extending this analysis one final step to pairwise correlations between two countries indices, we find that depending on the time period, between 35.6% and 56.4% of the country pairs are integrated at medium levels (see Table 4 for details). This indicates that many two-country event studies are also able to improve their estimates with the multi-factor estimation model. While the simulation results do not directly address situations with more than two countries, they do show that bias is an issue for the single-factor estimation model and suggest that a multi-factor model can offer some correction at levels of market integration and security coupling that are observed in actual market behavior. Extending the simulation to explicitly encompass settings with more than two countries is a goal for future research.

Table 4. Relationship Between a Country's Daily Index Returns and the World Market Returns (with that country's influence removed)

			Correlation with World Market			
Continent	**Country**	**Large Cap Index**	**2000-2012**	**2000-2003**	**2004-2007**	**2008-2012**
Africa	South Africa	MSCI SOUTH AFRICA	0.501 (Med)	0.404 (Med)	0.481 (Med)	0.591 (Med)
Asia	Australia	S&P ASX 200	0.528 (Med)	0.551 (Med)	0.493 (Med)	0.417 (Med)
Asia	Japan	TOPIX 100	0.486 (Med)	0.386 (Low)	0.436 (Med)	0.388 (Low)
Europe	France	FRANCE CAC 40	0.787 (Hi)	0.722 (Hi)	0.738 (Hi)	0.834 (Hi)
Europe	Germany	DAX 30	0.781 (Hi)	0.761 (Hi)	0.772 (Hi)	0.825 (Hi)
Europe	Netherlands	AEX INDEX	0.776 (Hi)	0.716 (Hi)	0.754 (Hi)	0.835 (Hi)
Europe	Switzerland	SWISS MARKET	0.665 (Med)	0.632 (Med)	0.652 (Med)	0.689 (Med)
Europe	UK	FTSE 100	0.709 (Hi)	0.64 (Med)	0.694 (Med)	0.776 (Hi)
North America	Canada	S&P TSX 60	0.519 (Med)	0.665 (Med)	0.394 (Low)	0.566 (Med)
North America	US	S&P 500	0.714 (Hi)	0.483 (Med)	0.655 (Med)	0.756 (Hi)
	Subtotals	High	5	3	3	5
		Medium	5	6	6	4
		Low	0	1	1	1

Conclusion

The value of IS investments in a global context is of interest to companies, foundations and governments. To provide insights about such value, IS scholars must evaluate and update our research methods as the business environment changes so that we can better attempt to provide timely and accurate insights. In this study we examine short-window event studies highlighted in recent IS literature reviews and find that few studies cross international boundaries, and most single-country event studies provide no rationale for that choice. After summarizing a multiple-factor world market model event study method proposed in the strategy literature to reduce bias when working with international data, we conduct a Monte Carlo simulation to find the conditions when this bias might occur.

Our simulation results indicate that, for conditions commonly observed in global markets, the single-factor model exhibits problematic estimates for which the multi-factor model is able to provide substantial correction. These results embody both a caution and an opportunity. The obvious caution is to avoid bias in estimates by explicitly making methodological allowances when conducting international short-window event studies. The opportunity, however, is much broader. Examining IT investments internationally is increasingly relevant and may help scholars answer questions as diverse as "What tax regimes best encourage investment in beneficial healthcare IT," or "Will the greatest return for corporate investments in the developing world locations come from a supply-chain IS deployment or an energy management system?" This study takes an initial step towards equipping scholars to answering such globally relevant questions by advocating for international event study investigations and evaluating a method to determine the market value effects of investment announcements more accurately.

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Chapter 3 Market Value of Carbon Management Systems: An International Investigation

Introduction

Climate change is a global challenge of vital importance to businesses and governments, both of which are responding with a variety of actions. Since the Kyoto Protocol was adopted in 1997, governments have undertaken a wide variety of policy responses to growing climate change awareness, including no regulation, voluntary or mandatory reporting of greenhouse gas (GHG) emissions by emitters and, in some cases, mandated reduction of GHG emissions (C Kauffmann, Less, & Teichmann, 2012). Many organizations also cite climate change as a critical issue for their future business success, including 66% of UN Global Compact member CEOs (Lacy, Cooper, Hayward, & Neuberger, 2010).

One organizational response to these diverse policies is to actively manage GHG emissions, even when not required to. To manage, however, organizations must first measure, creating the need for specialized information systems. For example, in 2001 Chevron Corporation announced its adoption of an information system to gather energy and GHG emissions data from its worldwide operations as part of the corporation's response to climate change (PR Newswire, 2001). This is one of the earliest examples of a public company announcing its adoption of a carbon management system (CMS), defined as enterprise information systems for measuring, mitigating, and reporting energy and GHG emissions. Adoption of CMS has increased over the decade following the

Chevron announcement (Rush & Melville, 2012) and is expected to represent a $5.7 billion market by 2017 (Navigant Research, 2011).

Despite rapid adoption, the business value of such systems is not well understood. CMS hold the promise of improved environmental performance, operational efficiencies and greater strategic self-knowledge, in addition to risk mitigation. For instance, Chevron predicted their CMS would allow them to set goals, identify improvement areas, evaluate capital projects and generate internal reports. Nonetheless, the financial impact of CMS adoption is not clearly predicted from prior literature on either IS adoption or sustainability investments.

This lack of clear prediction arises (at least partially) from uncertainty about whether CMS are perceived as a *technology for operational efficiency* or a *platform technology that enables innovation*. In the first conceptualization CMS could be simply viewed as a technology that supports operational efficiency by providing granular information about waste (CO2) and the inputs that create it (e.g. energy), thus enabling managers to reduce that waste by improving operational areas identified as most significant by the CMS. Prior sustainability research using the efficiency lens has found that while systems that measure, manage and allow the elimination of waste may lead to both innovation and profits, such measurement is costly and innovation success is uncertain (King & Lenox, 2002; Rennings & Rammer, 2011). These costs and uncertainty have been theorized as an explanation for why adopting environmental standards resulted in a negative shareholder wealth effects (King & Lenox, 2002; Paulraj & Jong, 2011). Additionally, recent IS literature has found that investment in cost-reducing information technologies are, on average, not associated with reduced operating expenses and that IT impact on profitability is most strongly associated with revenue growth (Mithas, Tafti, Bardhan, & Goh, 2012). Thus, if the role of CMS are to provide cost-savings alone, their adoption may not be perceived by investors as economically advantageous vis-à-vis alternate investments in IT that enable revenue growth.

The second conceptualization of CMS is as a platform technology that is both innovative itself and enables managers to undertake further innovation through the availability of new, granular data that was previously unavailable or gathered on an ad hoc basis. Prior IS research in this paradigm has found that innovative and platform information technologies are associated with positive shareholder wealth effects (Dos Santos, Peffers, & Mauer, 1993; Im, Dow, & Grover, 2001). As a technology that comprehensively spans a company's functional operations and can be configured to gather inputs from all its geographic regions, CMS may be perceived similarly to enterprise resource planning (ERP) systems that have been found to be associated with positive shareholder reaction for systems with greater functional and physical scope (Ranganathan & Brown, 2006). As prior empirical results from different research streams suggest no consistent prediction of how CMS adoption might impact investor perception of adopting firm financials, a specific investigation into the financial impacts of CMS with a focus on ascertaining how it is perceived by the firm's providers of capital could yield a contribution to both the IS and environmental sustainability literature.

Given the alternative conceptualizations of CMS and the implications for business value, the market value perspective offers several advantages. Shareholder reactions are meaningful because (1) they can indicate owners' collective beliefs that a firm is better or worse off from this 'green' investment decision, (2) changes to shareholder wealth directly affect the compensation of senior managers and are salient to organization decision makers, and (3) they are a useful aggregate measure of value for new information technology whose predominant dimensions of impact (revenues, cost reductions, risk reductions, etc.) are as yet unclear.

Despite the importance of the problem, we are not aware of any research that has analyzed whether CMS are perceived positively or negatively by shareholders. Moreover, it is unclear whether differences in the competitive and regulatory environments within which organizations adopt CMS affects business value, as suggested by prior business value research (Cheng & Nault, 2007; Melville, Gurbaxani, & Kraemer, 2007; Stiroh, 1998). Could an IS investment in one country's context be perceived positively where that same investment is received neutrally or negatively in another? What might drive these differences? While existing IS research suggests that industry and country level differences may affect business value (Dewan & Kraemer, 2000), we do not know how environmental management regulatory regimes may shape the business value of CMS, providing a new opportunity for theorizing and extending business value knowledge to a new domain. This study thus represents a first step at quantifying a financial impact of IS investments in countries with differing regulations by examining the shareholder wealth effects of CMS adoption in an international setting.

Our research question is thus: What are the financial impacts of Carbon Management Systems and how do they vary across regulatory regimes? To emphasize, this study within the Green IS/Green IT research stream is positioned squarely in IS research as it satisfies the three questions posed by Agarwal and Lucas[7] (2005): (1) It draws upon the unique nature of CMS to provide capabilities for environmental management that organizations lacked prior to their adoption of the technology, (2) Evaluating the business value of IS adoption is not possible without the artifact and (3) It can provide insights about differential IS value impacts as they vary by adoption timing and regulatory environment that may prove relevant to scholars and practitioners. This contributes to the core of the IS discipline via an examination of macro level impacts for a technology that is transforming organizational responses to environmental challenges (Agarwal & Lucas, 2005; Benbasat & Zmud, 2003).

We address our research question by investigating shareholder wealth effects, as defined by abnormal changes in market value, which result from CMS adoption announcements. These monetary changes in value are the aggregate result of investor buy and sell decisions immediately proximate to the company's announcement, which are driven by investor perceptions of that event. Examining investor perceptions with a real options perspective (Fichman, 2004) leads us to posit that investor reaction is driven by the underlying options to create value that CMS afford. These options to create value are influenced by a number of factors, with a particularly salient factor being the regulatory environment in which CMS adopting companies are operating. Climate change has elicited a variety of regulatory responses from different countries. We investigate the effects of this variation on investor perceptions of CMS value utilizing an international

[7] The three questions are (1) Is there a non-trivial aspect of the underlying theory that draws upon the unique nature of the IT artifact? (2) Would the phenomenon have been approached differently were the IT artifact not involved? (3) Does the research illuminate scholarly and practitioner understanding related to the construction, management, and effects of the IT artifact?

data set.[8] We are able to compare wealth effects in regulatory environments with and without national mandates for CO2 emissions reporting, while also considering the effects of early adopters and industry emissions intensity on value.

We identified 99 CMS adoption events across 12 countries, and three primary findings emerge from our empirical analysis. First, we find that shareholders do not appear to react positively to CMS announcements, as shareholder wealth effects are either not significant or negative, depending on the specification. Our second finding sheds further light on these results by illustrating that markets appear to penalize firms announcing CMS investments while under mandatory national GHG reporting. Lastly, we find that negative reactions to CMS appear to be dampening over time, consistent with literature theorizing a shift in the institutional logics of financial markets. Thus while it doesn't 'pay to be green' on average, our analysis suggests a 'cost to be green' for both early and already-regulated CMS adopters.

In the following sections we first review existing literature to develop theoretical understanding, review the results of relevant studies, and develop hypotheses for the current study. We then briefly review the event study methodology and its application in IS literature, discuss the methodological implications of conducting an international event study, and adopt the bias-reducing approach explicated in chapter 2. We then develop a regression model to further analyze our initial findings. Data and the not-insubstantial efforts that go into preparing it for an international event study are discussed. Analyses and results follow, and the paper concludes with discussion, limitations, and future research directions.

[8] It is estimated that 59% of the projected $1.1 billion carbon management software and services market in 2013 would be outside of North America (Navigant Research, 2011)

Literature Review

As a new type of information system, neither the financial or environmental value of CMS are currently well understood. Examining the characteristics and estimating the value of emerging classes of information systems from the market value perspective represents an established stream of research within the IS discipline, following such systems as Enterprise Resource Planning (ERP) systems (Hayes, Hunton, & Reck, 2001; Ranganathan & Brown, 2006), e-commerce (Subramani & Walden, 2001), Electronic Data Interchanges (EDI) between suppliers and customers (Mukhopadhyay, Kekre, & Kalathur, 1995), and others (see Konchitchki and O'Leary (2011) and Roztocki and Weistroffer (2011) for recent reviews). To contribute to this stream we next describe what CMS are, what is currently known about them, and why they offer a unique setting for theoretical and empirical perspectives relative to other classes of IS. We then develop hypotheses from theory foundations to predict their value and how it could differ with regulatory setting and adoption timing.

CMS Characteristics

Carbon Management Systems are closely related to, and in some cases grew out of energy management systems (the Chevron system is an example of this progression). While energy companies and utilities have long tracked their core strategic asset, the extension of that tracking to the energy's environmental impact in the form of GHG emissions is a relatively recent phenomenon. Both new companies and established software vendors have responded to this organizational interest from energy firms and other industries by creating commercially available CMS offerings (Liu & Stallaert, 2010), which have made rapid advances in the years leading up to 2010 (Melville &

Whisnant, 2014). While CMS features vary in the particulars, their core function is to aggregate and track internal and external data related to GHG-emitting processes, transform that data into normalized GHG emissions and then present it for analytics, reporting, compliance and auditing (Liu & Stallaert, 2010; Melville & Whisnant, 2014). Challenges and sources of variability in the operation and performance of this CMS functionality involve business processes, data capture and integration (e.g. many disparate data sources received in different formats with varying amounts of required data), limited availability of necessary technical or environmental managerial capabilities, and data quality (Melville & Whisnant, 2014).

Related CMS Studies

At the time of this writing, very few scholarly journal articles have been published on CMS. The two most closely related to this topic both utilize case studies (Corbett, 2013; Melville & Whisnant, 2014). Melville and Whisnant (2014) examine two organizations, one with an automated CMS and the other with a spreadsheet-based system with some elements of automation. The study focuses on the standards underlying CMS and the challenges organizations face in implementing and maintaining them. It also calls for a broad empirical investigation of the business value of CMS, which this study takes initial steps to answer. Corbett (2013) also uses case studies to examine the use of CMS in three organizations, two of which are using internally-developed CMS and one which has adopted a vendor-provided CMS. The study focuses on what software design principles persuade individuals within the organizations to alter their behavior, finding that personally-focused CMS help promote individuals' ecologically responsible behavior and that a hierarchy of design principles make CMS persuasive. These design principles vary by organizational context and are often different from those principles emphasized by vendors. Two key distinctions between Corbett (2013) and the present study are (1) Corbett's study explores individual action qualitatively rather than organizational business value quantitatively and (2) its scope is limited to individually-focused systems such as personal carbon calculators (Padgett, Steinemann, Clarke, & Vandenbergh, 2008), which are distinct from the organizationally-focused CMS investigated in this paper.

Other related studies also examine Green IS utilizing large empirical data sets of organizations. One such study examined market reaction to green IT initiative announcements, which the authors defined as "computing technologies that are energy-efficient and have minimal adverse impact on the environment" (Nishant, Teo, & Goh, 2011). After examining 39 firms that announced 160 green IT initiatives, such announcements were found to be significantly positive overall, but not for the category of investments that CMS resides in ("IT to support decision making", which was adapted from Corbett (2010)). Melville and Saldanha (2013) investigate the adoption antecedents for CMS, finding that though global climate agreements are not associated with CMS adoption, both firm-specific carbon reduction targets and managerial incentives are. The present study thus complements that study by investigating the specific financial benefits to shareholders associated with adoption, as well as investigating beyond the societal commitment of signing global climate agreements to the political fulfillment of that commitment through implementation of specific GHG reporting regulations.

Theory Foundations and Hypothesis Development

Given the state of knowledge about CMS and their characteristics, we begin our exploration of the value CMS provide firms by adopting real options perspective (Benaroch & Kauffman, 2000; Fichman, 2004; Otim, Dow, Grover, & Wong, 2012) in conjunction with the theoretic lenses of stakeholder and agency theories. Under the real options perspective, a technology investment creates a right but not an obligation to obtain future benefits associated with the future development and deployment of the technology (Fichman, 2004). The future benefits of a CMS are both direct and indirect. Direct benefits arise from CMS' efficiency conceptualization and include identifying opportunities for internal efficiencies from optimizing GHG-producing activities. Some evidence of firm profitability from waste prevention efforts that reduce emissions has been found (Hart & Ahuja, 1996; King & Lenox, 2002; Margolis & Walsh, 2001)(King & Lenox, 2002)(King and Lenox 2002)(King & Lenox, 2002)(King & Lenox, 2002)(King and Lenox 2002). Indirect benefits can include increasing future innovation, which has been theorized as the link between environmental sustainability, operating practices and improved financial performance (Surroca, Tribó, & Waddock, 2010). Indirect benefits may also be realized from firms cultivating and maintaining a positive reputation with its stakeholders.

According to stakeholder theory, trust, trustworthiness and cooperativeness can lead to a competitive advantage by reducing the costs associated with contracting between a firm and its stockholders, employees, customers, suppliers, creditors, communities and the general public (Hill & Jones, 1992; Jones, 1995). By adopting a CMS, firms gain the option to share their GHG emissions with their stakeholders. This sharing could result in financial benefits to firms that investors might perceive positively in a number of ways. One path to financial benefit is through better relationships with customers. By building trust and demonstrating cooperativeness, suppliers might improve (or at the very least maintain) their relationship with important customers such as Walmart that have requested GHG emissions information about the products they buy. Another path to financial benefit is through better risk management. By responding to large institutional investors that have requested GHG emissions data, firms can demonstrate that they are aware of their risks related to GHG emissions and are making investments in being able to respond to current and future changes in either the regulatory or natural environment. These reasons argue for CMS resulting in a positive financial benefit to the firm, and none of these options are easily available without having made the investment in a system to measure and monitor GHG emissions.

Alternately, investments in CMS software and procedures could result in negative shareholder wealth reactions if investors judge the cost of installing and maintaining a CMS to be greater than the value of the options it enables. This could occur for multiple reasons. For instance, investors may consider CMS to simply be a monitoring cost imposed on the firm by its stakeholders to ensure that its executives' conduct does not reflect a different appetite for risk than the investors have (both for direct risks to the business because of climate change-induced challenges and indirect risks via secondary effects such as climate-related regulation). Similarly, if investors perceive the value of the company's investment to be negligible while attempting to appear significant (aka 'greenwashing'), then their reaction to the costs of those expenditures would be negative or nominal (Laufer, 2003). For firms that must already follow regulations that mandate reporting of GHG emissions, investors may believe that the benefits of this reporting accrue disproportionately more to society as a whole than to the firm making the investment, representing a net financial loss and resulting in a negative reaction.

We find the argument for the creation of value through better stakeholder relationships and risk management to be more compelling and thus we hypothesize that

H1: *Abnormal stock market returns following CMS announcements will be positive.*

The set of future options that follow from a CMS are likely to vary with a number of factors that are either specific to the firm (e.g. size, announcement timing) or applicable to multiple firms (e.g. GHG reporting regulations and emissions intensity of the industry). Most salient in our international context are the regulatory differences among countries. Though cross-country (Dewan & Kraemer, 2000) and cross-industry (Melville, Kraemer, & Gurbaxani, 2004) studies of IS business value exist, we are not aware of any that account for specific regulations, further motivating our study.

One way to compare different environmental regulations and the impacts they have on companies is with an environmental policy life cycle framework. Such frameworks describe a general process that policy-making follows via a number of stages or phases. While the specific names of the stages vary from model to model, the ideas behind them are relatively stable (van Daalen, Dresen, & Janssen, 2002). We adopt a model from Lyon and Maxwell (2004) with four stages: Development, Politicization, Legislation and Implementation. In this model, the impact of environmental regulation on the firm increases at each successive stage. Similarly, the options available for organizations (potentially) subject to those regulations to influence their impacts are different at each stage of the life cycle as well. Countries that already have mandatory carbon reporting are further along in their carbon reporting policy life cycle, resulting in higher impacts to companies from the regulations and fewer options available as a response. A graphical representation of this model is presented in Figure 3. Market reaction to CMS adoption is likely to vary among countries at different points along the lifecycle impact curve, though the leading candidate reasons for these different reactions do not consistently predict whether the reactions will be more positive earlier or later in the life cycle impact curve.

On one hand, companies adopting CMS later in the regulation life cycle may have greater certainty success from better defined requirements and less risk associated with their implementation due to country-specific path dependencies such as localized knowledge. Regulations are likely to result in greater certainty for a system's requirements and the technology necessary to meet those requirements, reducing the likelihood of change over the course of the implementation project.

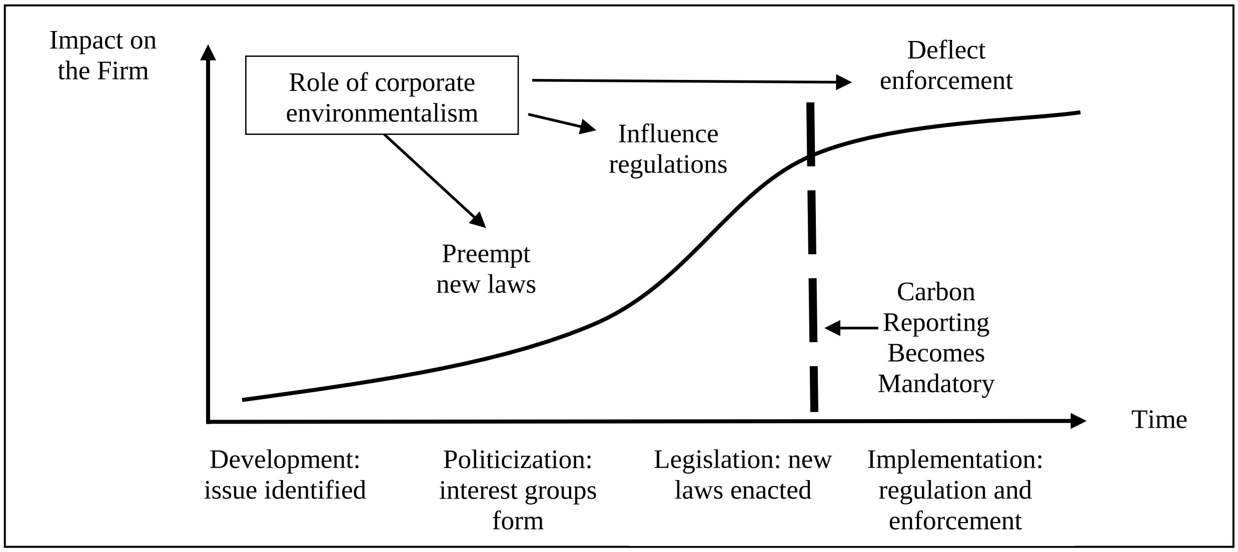

Figure 3. Carbon Reporting, Corporate Environmentalism and the Policy Life Cycle

Adapted from (Lyon & Maxwell, 2004, p. 7)

This is even more likely for firms located in jurisdictions that have extended politicization phases of the policy life cycle, as marked by voluntary reporting schemes or guidance documents that exist for a number of years prior to the reporting requirement, as many countries with mandatory reporting have (C Kauffmann et al., 2012). Next, a concentration of firms in an area subject to the same regulation will eventually generate localized knowledge within the labor force of how similar companies have complied with those same regulations. Finally, regulations increase the possibility that vendors will have customized, locale-specific technological solutions that reduce the risks of implementation (and may be less costly for certain segments). Lower risk would likely cause any anticipated positive benefit from the CMS investment to be more likely, thus resulting in markets reacting more positively to CMS adoption announcements in jurisdictions that already regulate GHG emissions.

On the other hand, an opposite reaction is predicted if companies adopting CMS earlier in the regulation life cycle may benefit from both a larger option set and investor beliefs about their organizational motivations for investments in CMS. In areas that are not subject to mandatory GHG regulation, markets could reasonably be expected to judge that firms adopting CMS do so endogenously based on firm-specific information relating to the capabilities of the firm to realize a positive financial benefit from the options the investment generates and would not otherwise be adopted since there are no penalties associated with not adopting. This is in contrast to firms adopting in countries that have implemented GHG emissions regulations, where investing in a CMS would likely be interpreted by markets as reacting to an exogenous shock and developing a real option set primarily to respond to this mandate.

Where no mandate exists, the policy life cycle suggests several options for firms to realize a lower impact (and thus lower costs) from regulation. One such option might be for a firm to voluntarily share their GHG emissions data with the community and public even when they are not obligated to do so. Such firms may benefit from reduced risk of community pressure or enforcement costs (Short & Toffel, 2008), and if they are not yet regulated, possibly from either reducing the possibility of or the new costs associated with future regulation (Lyon & Maxwell, 2004). In the non-regulated jurisdictions, adopting firms could be expected to have a more positive market reaction because of the likelihood of private information driving adoption and a larger set of options that the data generated by the CMS could inform. Of these possible explanations for varying market reactions in different regulatory regimes, we find the self-selection and option set size arguments to be more persuasive than decreased implementation risk, and thus hypothesize that:

H2: *Abnormal market value reactions will be more positive under regulatory regimes where GHG emissions reporting is not mandated*.

Timing is also anticipated to affect the market reaction to CMS announcements, though the direction of that influence remains uncertain. On one hand, early adopters may realize a larger option set for their investment than later adopters. One example would be the option to gain operational efficiencies uncovered by GHG emissions data when competitors are not equipped with the same types of data, resulting in comparatively better financial performance for early adopters. After such investments have become commonplace and are no longer strategic, the financial benefits of cost-reducing IS may be eventually competed away (Mithas et al., 2012). On the other hand, early adopters could be penalized because new types of IS are risky and uncertain in their value proposition, and because the perception of investors towards firm investments in CMS technologies may have become more positive over time.

Regarding risk, information systems implementations have historically been costly, difficult and uncertain in their success (Avison, Gregor, & Wilson, 2006; Markus & Robey, 2004). Early adopting companies that implement custom systems or that adopt early-generation versions of commercial systems disproportionately bear the risk of implementation failure (i.e. not realizing the benefits of the system in a cost effective manner). Regarding investor perceptions, markets may have grown more aware of the growth potential associated with sustainability disclosure and performance over time (Kangos, Lilak, Lopresti, Nieland, & O’Hara, 2011). Support for this idea is offered in a recent empirical study that posited that financial analysts have shifted from predominantly using agency logic to evaluate firms with high Corporate Social Responsibility (CSR) ratings, which include GHG reduction strategies, to a stakeholder focus, resulting in less pessimistic, and eventually optimistic forecasts for firms with high CSR (Ioannou & Serafeim, forthcoming). If CSR actions and investments have been historically met with pessimistic forecasts from analysts that have considerable influence on security prices, then it could be that an event study that relies on security prices is especially susceptible to the reversal of this trend, resulting in more positive reactions later. Of these two arguments, we find the latter to be the more persuasive possibility, and so hypothesize that:

H3: *Abnormal market value reactions will be more positive for later adopters than for earlier adopters*.

Having developed hypotheses on market reaction to CMS adoption announcements, we next describe the event study method, discuss several challenges associated with conducting an event study in an international context, contrast the standard approach to one that makes international affordances, and conclude with a discussion of how we accounted for these challenges in our methods and data.

Research Methodology

Conventional Event Study Approach

Measuring financial value that might be achieved through different mechanisms (e.g. operating cost efficiency, increased innovation), each with a unique time horizon, presents a challenge. In the case of CMS, theory predicts that cost reduction, revenue enhancement, risk reduction or increased option sets might all contribute to a CMS's financial impacts on a company, with potentially different directions and timing. Given this uncertainty, a generalized and robust proxy for financial value is desired. Since being first proposed in the accounting and finance literatures, the event study has proven to be an enduring method for investigating uncertain financial impacts of corporate actions by examining stock market reactions to those actions (Ball & Brown, 1968; Fama, Fisher, Jensen, & Roll, 1969). Event studies are frequently used in IS research, as well as other fields such as finance, accounting, macroeconomics and management (Fama, 1991; Konchitchki & O'Leary, 2011).

Event studies provide an inclusive metric of financial value stated in terms of shareholder wealth effects. Changes in shareholder wealth capture the cumulative effect of shareholder reactions to an IS investment's announcement. This is in contrast to attempting to measure specific constructs such as cost reduction, innovation, or risk mitigation across different companies and time horizons and make them comparable post hoc. This inclusive measure has been applied to classes of IS investment in the past, finding, for instance, positive value associated with IS categorized as innovative (Dos Santos et al., 1993), transformational (Dehning, Richardson, & Zmud, 2003) or representing infrastructure (Chatterjee, Pacini, & Sambamurthy, 2002). Event studies have also investigated IS with specific feature sets, finding high returns for business-to-consumer investments in e-commerce during the dot-com boom (Subramani & Walden, 2001) and positive value for ERP investments with greater functional and organizational scope (Ranganathan & Brown, 2006).

Event studies are also well suited for evaluating emerging technologies that lack widespread measures of accounting value or that have other features that pose significant challenges to compiling their financial impact (e.g. being located in multiple countries with different accounting standards). The method's theoretical basis is a semi-strong efficient market hypothesis which states that when market participants anticipate an investment will impact the present value of a firm's future cash flows, the stock price will adjust to incorporate that impact (Fama, 1991). Under this assumption, if market participants believe a CMS investment will reduce costs or increase revenues (e.g. via reduced risks or increased options sets) by more than the initial outlay plus maintenance, we expect to observe positive abnormal returns following the announcement. This is not to say that the markets will correctly and precisely determine the exact dollar impact of an investment (Malkiel, 2003), but rather that by examining the shareholder wealth effects following a CMS announcement we can measure how, in aggregate, investors *perceive* the value of the investment. The results of this perception are priced into the security, resulting in actual changes to shareholder wealth. There is some evidence to believe that markets are becoming more aware of and adept at incorporating environmental information appropriately into security prices. This evidence includes both a growing segment of the stock market in the US and globally made up of institutional investors whose stated goals include investing in environmentally and socially responsible companies (Ramchander, Schwebach, & Staking, 2012), as well as the shift in analyst logics to stop penalizing CSR (Ioannou & Serafeim, forthcoming).

International Event Study Considerations

As noted in chapter 2 of this dissertation, despite the event study's use and acceptance within the field, few IS event studies appear to span international boundaries (Roztocki & Weistroffer, 2011; Rush & Melville, 2014). This is in contrast to an increase in international event studies in related management disciplines (Campbell, Cowan, & Salotti, 2010), where international event studies are considered an important tool to study the impact of factors that are relatively constant within a country, but can vary widely between countries (DeFond, Hung, & Trezevant, 2007).

In attempting to carefully follow recommendations from prior scholars that conducted international event studies, we encountered Park's (2004) method of calculating returns. This multi-factor method takes into account the influence of international markets and exchange rates, which if ignored, could lead to biased estimates in the event size. Because this method is described in detail in the essay contained in chapter 2, we will only summarize the main components here.

Multi-Factor Model

Park's (2004) alternate specification of CAR_i was proposed for management scholars to reduce potential sources of error in calculating their abnormal returns. This approach controls for currency exchange rate changes (X_{jt}) for country *j* and the co-movement of a stock with securities markets other than its own through the construction of a world market (R_{wmt}). This world market can be approximated by indices such as the Financial Times and Stock Exchange (FTSE) All World Index or the Morgan Stanley Capital International Europe Australasia and Far East (MSCI EAFE) index and should be adjusted to subtract the influence of the focal market (R_{mt}) if that market is represented in the index. In this model, R^*_{ijt} is formulated as shown in equation 1B to construct the counterfactual return for what a stock's return would have been without the event.

$$R^*_{ijt} = \alpha_i + \beta_i R_{mjt} + \gamma_i R_{wmt} + \delta_i X_{jt} + \epsilon_{ijt} \quad \text{(1B)}$$

Under this specification, CAR_i becomes

$$CAR_i = \sum_{t=window\ start}^{t=window\ end} R_{it} - (\alpha_i + \beta_i R_{mjt} + \gamma_i R_{wmt} + \delta_i X_{jt}) \quad \text{(2)}$$

Without this alternate specification of the model, MCAR estimations are biased because a relevant independent variable is omitted (Greene, 2003, p. 148). As presented in chapter 2, the error correction achieved from using the multi-factor model varies with market integration and security/market coupling. For the market conditions observed during our study, this error correction improvement over the single-factor model ranges from 44% to 99%. Given these conditions, the multi-factor model is most appropriate for our international analysis and is adopted to avoid biased estimates. Having selected a model for the initial analysis of our hypotheses, we next turn to a brief discussion of the model for our secondary regression analysis.

Regression Analysis Model

Our first hypothesis predicting positive MCAR for CMS announcements can be tested directly using the multi-factor model described above. Our second hypothesis predicting more positive reactions in jurisdictions without regulations can also be tested in the same way after splitting the sample along the dimension of whether or not the firms are regulated. While we illustrate such a split, we also conduct a regression analysis to include important controls that have been identified by prior studies. These include firm size, industry, timing of announcement and trading volume. The impact of a CMS investment on a firm's financial performance is anticipated to vary with firm size (Im et al., 2001), industry differences (Chatterjee et al., 2002; Dos Santos et al., 1993; Im et al., 2001; Ranganathan & Brown, 2006), and announcement timing (Bose & Pal, 2012; Im et al., 2001). All of these can influence the opportunities that the firm has to realize cost savings and revenue enhancements from the investment. Controls for industry are additionally important because industries differ greatly in their carbon emissions,[9] thus varying the opportunity for value to be realized from a carbon management system. To account for these differences, and to test the robustness of the initial findings, the following regression model is estimated using OLS:

$$CAR_i = \alpha_i + \beta_1 Regulated + \beta_2 Size + \beta_3 EarlyAdopter$$

$$+\beta_4 HiEmissionsIndustry + \beta_5 Volume \quad (3)$$

Size is operationalized as the log of the market value of shares available to trade (i.e. free floating) (ln(MVFF)), EarlyAdopter is a binary variable that is non-zero if the announcement is on or before Dec 31, 2009 (roughly splitting the sample into 1/3 early adopters, 2/3 later adopters), and HiEmissionsIndustry is a binary variable with a value of 1 for high C02 emission industries, which are defined as the materials, utilities and energy sectors of the Global Industry Classification Standard (GICS). The other 7 sectors are low emissions and receive a value of 0. This industry classification follows established practice in professional carbon reporting (Kangos et al., 2011). Volume is

[9] See http://www.epa.gov/climatechange/emissions/usgginventory.html for illustrations

operationalized as the log of shares traded that day (ln(VO)). Regulated is a binary variable derived by identifying the country that each organization is headquartered in, then ascertaining if the organization was subject to nationally-mandated reporting of greenhouse gases at the time it announced the adoption of a carbon management system. While many countries operated voluntary reporting schemes before they mandated GHG reporting (Kauffmann, Less, & Teichmann, 2012), for the purposes of this study only mandated reporting is considered as "regulated."

A summary of the laws, conditions and jurisdictions applicable to the companies in this study are presented in Table 5 and their effective dates are depicted in Figure 4. For the purposes of the analyses in this paper, if a company is not subject to mandatory reporting at the national level, even if they state they report voluntarily under the same standards, they are classified as not being regulated (e.g. Dominos in Australia, which was not subject to a mandatory national GHG reporting regulation at the time of their announcement).

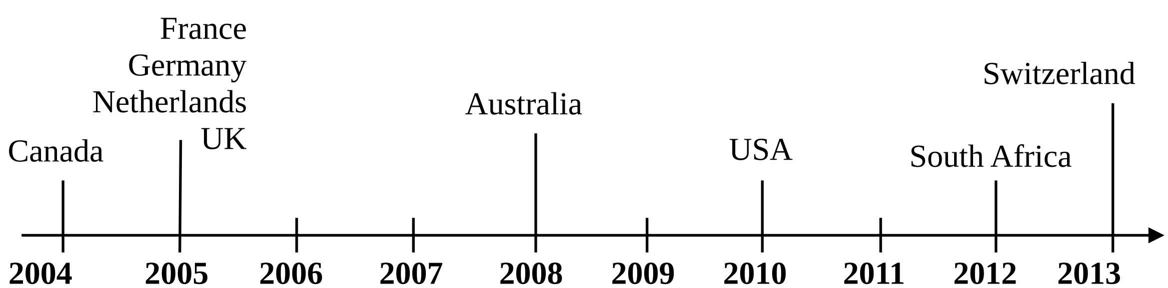

Figure 4. Start of Mandatory Carbon Reporting for Countries in Sample

Notes: *Required reporting expanded to additional facilities by Canada in 2010, the UK in 2013*

Table 5. Countries and GHG Reporting Regulations

Country	Regulation	Effective Date	Applicable to
USA	Clean Air Act (after EPA GHG endangerment finding)	Jan 2010 (some Jan 2011)	Fossil fuel suppliers, industrial gas suppliers, as well as direct GHG emitters emitting >25,000 MT CO2e/yr.
Australia	National Greenhouse and Energy Reporting Act (NGER)[10]	July 2008	>125,000 tonnes CO2e per year at the corporate level (in 08-09, 87.5 kt in 09-10, 50kt in 10-11). 25kt facility threshold
Japan	Act on Promotion of Global Warming Countermeasures	April 2006	Businesses with >20 full-time employees must report GHG emissions for each site that exceeds 3,000 tons CO2e.
Canada	Canadian Environmental Protection Act	Jan 2004	2004-2009 >=100,000 tons CO2e, 2010- >=50,000 tons
France, Germany, Netherlands, UK	EU Emissions Trading Scheme	Jan 2005	CO2 from power & heat generation, energy-intensive industries (oil refineries, steel works, iron, aluminum, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids & bulk organic chemicals), civil aviation (added in Jan 2012), N2O from nitric, adipic glyoxal and glyoxic acids, PFCs from aluminum production
UK	Mandatory Carbon Reporting (Companies Act 2006 (Strategic and Directors' Reports))	April 2013	Companies Act 2006 (Strategic and Directors' Reports) Regulations 2013 all quoted companies are required to report their annual global carbon equivalence emissions in their directors' report
South Africa	National Energy Act – Regulation 142	Feb 2012	
Switzerland	CO2 Act	Jan 2013	Optional 2008-2012, Mandatory 2013-2020. Heating Oil Levy 2008-current, Climate cent on transport fuels 2005-current

Data

Collection

The data for this study were collected from three types of sources. First, financial data and stock market data were retrieved from Thomson DataStream (TDS). This is a

[10] Though Australia repealed its carbon pricing mechanism (contained in the Clean Energy Bill of 2011, effective July 2012) in 2014, the repeal did not affect the reporting obligations under NGER (http://www.cleanenergyregulator.gov.au/Carbon-Pricing-Mechanism/Carbon-pricing-mechanism-repeal/Pages/default.aspx)

commonly used source of data for international financial returns, and can be used reliably after appropriate data cleaning procedures such as removing penny stocks, calculating returns directly from prices and removing delisted firms (Ince & Porter, 2006). Second, event announcements were gathered primarily from the Lexis-Nexis Academic database using the “All News-English” source, which indexes 6,090 English-language full-text news sources with global coverage. These sources include PR Newswire and Business Wire, consistent with other IS event studies, but also capture the international sources necessary for this study. The third type of information sources are adopting firm, CMS vendor and sustainability industry websites, as well as carbon consulting ventures and sustainability news sites (e.g. http://www.greentechmedia.com). Because of their focus on the company, vendor or issue of carbon management, these sources occasionally contained additional information on adoption time or nature of the technology adopted beyond what was gathered in the initial press release or news report. In only a few cases did these sites report a company’s CMS adoption that was not available in the Lexis-Nexis database.

Data collection was performed by compiling a list of CMS vendors and customers from the literature and popularly available sources, yielding 423 organization/CMS vendor pairs. After eliminating non-publicly traded organizations, searches of newswire archives for the remaining companies and their CMS vendor name, CMS product name, and/or keywords specific to CMS adoptions were performed. Careful examinations of CMS vendor and consultant websites and topic-specific third party news sites were conducted as well. In total, these searches and examinations yielded a list of 106 CMS adoption announcements. After eliminating those for which an event date was not available (e.g. some announcements archived on company websites were not dated) or that did not indicate that the company was specifically adopting the carbon portion of the software (even if they had been identified as carbon customers in the initial screen), 99 announcements remained. The timing and location of these 99 announcements are presented in Table 6. Eight of the announcements did not have the requisite data in TD, yielding a final sample of 90 announcements, whose summary statistics are presented in Table 7.

Table 6. CMS Adoption Year and Country

Year	Count		Country	Count
2001	1		Australia	8
2002	0		Canada	2
2003	0		China	1
2004	1		Dubai	1
2005	4		France	2
2006	1		Germany	2
2007	1		Japan	2
2008	8		Netherlands	1
2009	18		South Africa	3
2010	33		Switzerland	2
2011	24		UK	10
2012	8		US	65
Total	99		**Total:**	99

Table 7. Sample Descriptive Statistics (n=90)

Variable	Min	Max	Mean	S.D.	Median
Stock Event Price (USD)	2.16	117500	1445.67	12589.01	29.85
logTotAssetsUSD	8.47	24.14	16.46	2.2	16.32
logMVFFUSD	4.25	14.75	9.05	1.77	8.99
emit01	0	1	0.2	0.4	0
RegEff01	0	1	0.22	0.42	0
early01	0	1	0.34	0.48	0

Preparation

Before conducting an international event study analyses, several data preparation steps are necessary, most notably removing confounding events and accounting for the lack of synchronization in stock market trading hours (MacKinlay, 1997; Park, 2004).

Remove Confounding Events

International event studies of heterogeneous firms and domestic environments are more likely to contain confounding events (Park, 2004). Because they may be perceived as a type of corporate social responsibility (CSR), the adoption of carbon management systems may be additionally susceptible to interference from confounding events (McWilliams and Siegel, 1997). To eliminate these sources of abnormal returns, we carefully examined newspaper reports concerning each company for 7 calendar days before and after their announcement date, reviewing 11,276 articles to identify 143 of which contained a confounding event per the definitions from prior literature[11]. In keeping with prior event studies, any announcements that occur between November 2007 and September 2008 are also excluded (Ba, Lisic, Liu, & Stallaert, 2013; Goldstein, Chernobai, & Benaroch, 2011). This time frame was selected to exclude the greatest disruptions from the financial crisis without discarding too many observations. Three events were eliminated in this manner.

Synchronize International Markets

We accommodate the lack of synchronization in international market trading hours by lagging the security and market returns by one day for Australian and Asian companies (those traded on the Australian Securities Exchange, Tokyo Stock Exchange

[11] See Appendix A for details.

and Shanghai Stock Exchange). Our analysis contains a slight variation from Park (2004) in that we do not similarly lag foreign exchange rate changes. The reason for this is we are using the WM/Reuters Closing Spot Rates, which are fixed at 16:00 UK time (10 hours after the close of the Australian Markets and 8 hours before their next open). Thus, the exchange rates are treated in the same manner as market information from Europe and are not adjusted.

Other Data Considerations

One additional concern that impacts the calculation of the MCAR's significance is the assumption that no window for any firm in the sample overlaps with another firm in that same sample. This is known as clustering and should be avoided to allow the calculation of the aggregated CARs' significance without concern to the covariance between securities (which should be zero for non-overlapping event windows in the same market). The violation of the no-clustering assumption leads to the underlying distributional assumptions relied on by parametric significance tests to not hold, though non-parametric tests are still viable. While not critical in our international analysis due to our reliance on non-parametric tests, we demonstrate the impact of clustering on our analyses by presenting results before and after excluding clustered events. When we did so, event clusters were resolved before removing confounded events by a process retaining events with the fewest confounds (ties resolved through randomization).

Analysis and Results

Portfolio and Split Analyses

Results from using the single factor model to calculate MCAR are presented in the first column of Table 8. All other columns present the results of using the multi-factor method. The signs and significance of all estimates are similar under both models, but as predicted by Park, the magnitude is different, with the size of the calculated effect being somewhat larger when using the multi-factor model. An event window of (-1, 1) is selected for primary analyses in keeping with prior literature (Chatterjee et al., 2002; Dehning et al., 2003; Ranganathan & Brown, 2006) and because the slightly more conservative two-day window also used in the literature (Im et al., 2001) is affected by the date adjustment required for this international analysis.

Table 8. MCAR and Significance Tests for (-1, 1) Window

Model	Sample / Split	n	MCAR	Patell Test p	Pos:Neg	Gen Sign p
Single-Factor	**Portfolio 1**: All Events	90	-0.879%*	0.0821	41:49	0.2946
Multi-Factor	**Portfolio 1**: All Events	90	-0.957%*	0.0604	37:53*	0.0799
	Portfolio 2: Exclude Confounded and Financial Crisis	60	-0.599%	0.2708	26:34	0.2131
	Portfolio 2: Unregulated Split	49	-0.485%	0.3752	23:26	0.4046
	Portfolio 2: Regulated Split	11	-1.108%	0.2253	3:8*	0.0886
	Portfolio 2: Early Adopter Split	19	-1.536%	0.1863	7:12	0.1509
	Portfolio 2: Later Adopter Split	41	-0.165%	0.4477	19:22	0.3977
	Portfolio 3: Exclude Confounded, Financial Crisis and Clustered	49	-0.989%	0.1667	19:30*	0.0835
	Portfolio 3: US Only Split	30	-0.572%	0.4252	14:16	0.3907
	Portfolio 3: World Ex US Split	19	-1.647%*	0.0940	5:14**	0.0306

***** ***p<.1,*** ****** ***p<.05,*** ******* ***p<.001***

A preliminary analysis of the full-panel (Portfolio 1) suggests a negative and (weakly) significant reaction to CMS adoption announcements. This initial finding does not exclude confounding events, however, and any estimations include the impact of those events as well as the CMS adoption. We form portfolio 2 by excluding confounding events and then test H1 by observing whether the parametric or non-parametric significance tests indicate a MCAR estimation or generalized sign test that are significantly different from zero. Neither test is significant, thus the first hypothesis that abnormal stock market returns from CMS announcements will be positive is *not supported*.

Two observations can be made. First, that a significant and negative effect was present prior to removing confounding events but absent after doing so suggests that companies may announce CMS at the same time as other news that the market reacts negatively to. Second, it is interesting that after eliminating any clustered events (to form Portfolio 3) there are more negative reactions than positive (compared to the estimation period), but the difference is only large enough for the generalized sign test to be weakly significant (p=.073) and the MCAR is not significant. We thus conclude that there are no patterns indicating a positive financial impact from CMS, and instead there is a weak indication of a negative reaction for the portfolio as a whole. After a brief note about parametric tests, we further investigate that negative reaction.

As we just observed, none of the estimates of the effect size (though they all are estimated to be negative) are significantly different than zero using the Patell parametric test. However, the lack of significance using parametric tests may be expected in an international setting (Campbell et al., 2010). This is due to the more likely violation of the assumptions that the test makes when it is applied to the returns of financial markets outside of the US. The recommendation in prior literature is to give more weight to non-parametric tests such as the generalized sign test, which generally remain well specified. Thus, parametric results should be approached with caution, and the non-parametric results (indicating a positive or negative reaction) are considered more reliable in an international setting, giving an indication that is appropriate to proceed to further analysis to understand this weakly negative result.

We test the second hypothesis that abnormal market value reactions will be more positive under regulatory regimes where GHG emissions reporting is not mandated with both a split analysis and a regression analysis. First, the results of Portfolio 2's initial split between regulated and non-regulated firms suggests that in unregulated markets, there is no reaction significantly different from zero in direction or magnitude. However, in regulated markets, there is a tendency for firms to experience negative reactions to CMS announcements. The p-value for the generalized sign test's negative result is somewhat weak (.057), but the small numbers of regulated adopters make this effect harder to substantiate. Additional evidence for negative reactions in a non-regulated market are supported by Portfolio 3's split between the US (representing the largest unregulated market for almost all of the sample) and the rest of the world (which is predominantly regulated). In this analysis, non-US firms react negatively to CMS adoption announcements, (p=.02), with an average effect size of -1.657% that is weakly significant with a parametric Patell test (p=.095). Taken together, these patterns and signs suggest that CMS adoption in countries without CMS regulations have no impact on shareholder wealth, but for countries that do have GHG regulations, the announcements are received negatively and reduce shareholder wealth. Thus, hypothesis 2 that unregulated CMS adopters would react more positively than unregulated adopters is *supported*. No evidence is found in the split analysis to support or reject H3, so we next turn to the regression analysis.

Regression Analysis

To include important controls and further understand the initial findings, we next conduct regression analyses of the calculated CARs. Recall that equation (3) specifies the regression

$$CAR_i = \alpha_i + \beta_1 Regulated + \beta_2 Size + \beta_3 EarlyAdopter$$

$$+\beta_4 HiEmissionsIndustry + \beta_5 Volume \qquad (3)$$

The results of the regression are presented in Table 9. After accounting for clustering (Portfolio 3), the (-1, 1) window provides further evidence for our findings with respect to H2 (that regulated CMS adopters are penalized). Additionally, the regression analysis provides evidence that, after controlling for regulation, size, industry emissions intensity and trading volume, early adopters are penalized, not rewarded, with the magnitude of the penalty being near that of the penalty for regulation.

The sign and significance of the intercept also provides additional evidence that, after including the above controls, the average impact of CMS adoption is negative and significant. Taken together with the analysis of the portfolio splits, these results indicate support for two of the three hypotheses. These are summarized in Table 10.

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Table 9. Regression Results for Portfolio 3 in the (-1, 1) Window

Covariate	Estimate (std err) [p-val]
intercept	-0.05313** (0.01983) [0.0106]
RegEff01	-0.02241** (0.0104) [0.0371]
logMVFF	0.00315 (0.00263) [0.2386]
early01	-0.02469** (0.00926) [0.0109]
emit01	-0.00311 (0.00988) [0.7541]
logvolume	0.00419* (0.0024) [0.0884]
n	47
R^2	0.284
Adj R^2	0.196
F-stat [p-val]	3.248 [0.015]

Table 10. Summary of Support for Hypotheses

Hypothesis	Result	Observed Effect
H1: Abnormal stock market returns following CMS announcements will be positive.	Not Supported	Not significant or negative reaction, depending on specification
H2: Abnormal market value reactions will be more positive under regulatory regimes where GHG emissions reporting is not mandated.	Supported	Regulated companies have more negative (-) CAR than unregulated companies
H3: Abnormal market value reactions will be more positive for later adopters than for earlier adopters.	Supported	Early adopters are penalized while later adopters are not

Discussion

While theory suggests a positive financial impact of adopting CMS overall, the statistical analyses of our data do not confirm this. Rather, they show that, after controlling for regulation, early adoption, industry size and trading volume, there is, on average, a negative shareholder wealth effect. This effect is not observable in the pooled model after removing confounding events with negative reactions, which appear to be released around the same time as CMS announcements. Additionally, the overall patterns and signs in the result provide some evidence that CMS adopters in countries without national GHG emissions reporting regulations are not penalized, but CMS adopters in regulated countries are. We next discuss several potential reasons for this seemingly counter-intuitive result, including a company's innovation capability and self-selection effects. We follow that by a discussion of our timing effects findings, and the potential interaction between the timing and regulation findings.

When considering why regulated firms might exhibit negative returns from CMS, we first return to the theory that innovation forms the link between environmental sustainability and financial benefits (Surroca et al., 2010). Under this paradigm, firms that are required to measure and report GHG emissions likely vary in their ability to innovate, especially around a required compliance measure. Thus, ceteris paribus, their CMS adoption is less likely to result in financially-beneficial innovations enabled by this new source of data than firms that have a choice of whether or not to adopt. The counter example to this can be found in non-regulated environments where it likely that a firm adopting a CMS perceives a specific benefit will be gained from it. For a shareholder evaluating the company's announcement, they might judge that absent a regulatory mandate, a firm is acting rationally in their adoption of a CMS and will thus not penalize it.

With regard to timing, our data show that early adopters are penalized for CMS adoption whereas later adopters are not. If a disproportionate number of regulated adopters are also early adopters, one effect could be driving the other. Indeed, since ¾ of the regulated firms in the split analysis were also early adopters, this might be the driving explanation, if it were not for the regression results. These indicate that, after controlling for regulation and other factors, early adopters are still penalized.

One possible reason for this is the organizational structure into which CMS are deployed. Unlike prior IS which are largely managed by professional IT organizations within a company or through outsourcing, CMS are often managed and operated (at least initially) under the operations or sustainability business units (Melville & Whisnant, 2014). These managers are likely not versed in or resourced to take advantage of best practices in implementing and utilizing complex information systems. Thus, they might be expected by markets to lack the ability to fully exploit the potential value of a CMS. As adoption increases and commercial offerings become more standardized, the pitfalls of non-professional management are reduced through standardization and an increase in familiarity with the offerings and capabilities of the CMS. In the same way that financial benefits are competed away through standardization of IS offerings (Mithas et al., 2012), so to could the financial risks be mitigated by the same mechanisms.

Conclusion

Limitations

As with all studies, the results presented here are subject to a number of limitations. First, the category of software described as CMS has evolved and matured over the duration of the study, limiting the direct comparability of even vendor-supplied systems from the beginning of the study to those at the end. While we attempted to control for this by examining timing effects, an objective measure of software maturity would provide a more fine-grained control if it were available.

A second limitation is the restriction of the keyword and news searches to English language news sources. While we utilized the largest source of English language news available to us (that also included translations from many world news sources), such a limitation will necessarily exclude some international CMS adoptions. Companies that choose to announce in only their local languages are less likely to be large multi-nations and more likely to not operate in English-speaking jurisdictions than those included in our sample. To the extent that size is associated with the ability to innovate and realize the benefits of a CMS, then including these missed companies would likely only increase the observed negative reaction.

Finally, as an event study, the results obtained are not conclusively causal nor are they guaranteed to be long lasting. Rather, by restricting the event window to 3 days centered on the event date and by doing an extensive search for confounding events, we have attempted to remove alternative explanations for observed abnormal returns.

Future Research

Future research opportunities include the extension of these findings to longer horizons and accounting measures of firm characteristics such as operational efficiency and profitability. While understanding the value CMS bring to a business may provide evidence towards explaining the motivation for why businesses adopt (or do not adopt) CMS, further study in this direction is needed and provides an area for future research.

In this paper we have attempted to quantify a financial impact of carbon management systems on an organization's shareholders in an international setting. Our primary findings are that there is no observed financial penalty associated with CMS adoption until a number of controls are included. There are, however, penalties for adopters within jurisdictions that mandate the reporting of GHG emissions at the national level and an additional penalty for early adopters. These represent a first step at both exploring both the business value of CMS and investor perceptions of CMS, as well as indicating possible reasons for their adoption beyond regulatory compliance on one end of the spectrum and greenwashing on the other.

Appendix A: Data Preparation Details

Confounding Events

The search for confounding events was conducted ±7 days around the CMS adoption announcement utilizing the Lexis-Nexis Academic "All News" searches containing the company name or tagged by Lexis Nexis with the company's ticker symbol. These results returned 11,276 articles, 143 of which contained a confounding event.

Our definition of a confounding event was constructed from prior literature and captures events likely to affect the market price of a security. These include: dividend declarations, earnings announcements, mergers/acquisitions/divestiture, tender offers, debt offerings, bankruptcy filings, major income tax-related events, change of senior management/executives/significant personnel restructurings, declaration of analyst ratings (stock upgrades/downgrades), lawsuits, major government contracts, and announcements of new products. To this list we add other "Green" news and regulatory action substantial enough to be reported on in the international press. Table 11 gives counts of each type of confounding event found, along with prior literature that identified it.

Table 11. Confounding Announcement Counts and Supporting Literature

Confounding Event Category	Count (Total = 143)	Identified as a confounding event in prior literature
Earnings	24	Paulraj and Jong (2011); Chatterjee et al. (2002); Im et al. (2001); Bose and Pal (2012); Konchitchki and O'Leary (2011); Dewan and Ren (2007); McWilliams and Siegel (1997)
Leadership change	23	Bose and Pal (2012); Konchitchki and O'Leary (2011); Dewan and Ren (2007); McWilliams and Siegel (1997)

Analyst rating	15	Bose and Pal (2012); Dewan and Ren (2007)
Lawsuit	15	Konchitchki and O'Leary (2011); Dewan and Ren (2007); McWilliams and Siegel (1997)
Divestiture	12	McWilliams and Siegel (1997)
Regulatory action	11	
New product	8	McWilliams and Siegel (1997)
Acquisition	8	Chatterjee et al. (2002); Bose and Pal (2012); Dewan and Ren (2007)
Debt	6	
Major new contract	6	McWilliams and Siegel (1997)
Merger	5[12]	Chatterjee et al. (2002); Im et al. (2001); Bose and Pal (2012); Konchitchki and O'Leary (2011); Dewan and Ren (2007); McWilliams and Siegel (1997)
Other green news	4	<New in this study>
Dividend declaration	2	Paulraj and Jong (2011); Im et al. (2001); Bose and Pal (2012); Konchitchki and O'Leary (2011); McWilliams and Siegel (1997)
Layoffs/Restructuring	2	Dewan and Ren (2007) (merged into leadership as 'significant personnel changes)
Economic news	1	Dewan and Ren (2007) (specifically Site traffic volumes)
Stock or Tender offerings	1	Chatterjee et al. (2002); Konchitchki and O'Leary (2011)
Bankruptcy	0	Chatterjee et al. (2002)
Major Income Tax Related Events	0	Chatterjee et al. (2002)
Joint Venture Announcements	0	Konchitchki and O'Leary (2011)

Synchronize International Markets

The procedure for lagging the security and market returns by one day for Australian and Asian companies (those traded on the Australian Securities Exchange, Tokyo Stock Exchange and Shanghai Stock Exchange) is as follows. All Asian/Australian company returns and rates from a day (e.g. the 17th) were attributed to the day before (e.g. on the 16th) so that the prediction of the security return for the 17th in Australia will depend on what the domestic market had done that same day (on the 17th) and on what the world market had done on the 16th (NY closes on the 16th 3 hours before

[12] One of the 'merger' events is a dummy to indicate that a merger was announced between the estimation period and the event window, changing the relationship between the company's security price and the market (because it was acquired).

Australia opens on the 17th). To say it would depend on what happened later in the day on the 17th would be to violate the temporal ordering condition of causality.

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Chapter 4 Impact of Enterprise Information Systems on GHG Pollution Emissions Reduction[13]

Introduction

Businesses and other large organizations around the world are increasingly under pressure to measure, disclose, and reduce their greenhouse gas (GHG) emissions. External sources of pressure include government schemes and regulations to encourage or require them to report and limit their greenhouse gas emissions (Kauffmann, Tébar Less, & Teichmann, 2012). Where regulations are not in place, organizations are still subject to pressure from large shareholders and third party groups to measure and disclose their GHG emissions (Reid & Toffel, 2009). Large customers such as Walmart are also requesting GHG information and reductions from their supply chain partners[14]. Taken together, governmental, shareholder, and supply chain pressures represent a compelling reason for companies to measure and manage their GHG emissions. The ultimate purpose of pressure from external groups is to reduce anthropogenic GHG emissions, thus lowering concentrations of GHGs in the atmosphere and eventually reducing the global impact of climate change and its consequences (IPCC, 2013).

Management is not possible without measurement, however, and measuring and managing GHG emissions can be a complex task for large organizations, necessitating

[13] The author gratefully acknowledges the contributions of Ronald Ramirez and Kevin Kobelsky in editing earlier versions of this text for submission to ICIS 2015, providing useful input and feedback for the conceptual model, and providing access to portions of the data to enable the analyses in this paper.

[14] http://news.walmart.com/news-archive/2010/02/25/walmart-announces-goal-to-eliminate-20-million-metric-tons-of-greenhouse-gas-emissions-from-global-supply-chain

the use of information systems (IS). For example, the accounting coalition International Integrated Reporting Council (IIRC) notes in their international <IR> framework that organizations must put measurement and monitoring systems in place to provide the information necessary for integrated reporting (IIRC, 2013). Scholars have documented early IS being developed to facilitate these efforts (Corbett, 2013; Melville & Whisnant, 2014; Rush & Melville, 2012). While IS have been found to enable corporate social responsibility strategy (Benitez-Amado & Walczuch, 2012), impact electricity usage (Cho, Lee, & Kim, 2007; Collard, Fève, & Portier, 2005), and affect firm financial performance (Mithas, Tafti, Bardhan, & Goh, 2012), questions of the extent and pathways through which firms can utilize IS and related capabilities to reduce GHG emissions remain unanswered.

To fill this gap, professional and academic case studies have been published that detail company efforts to utilize information systems to reduce greenhouse gas emissions (Melville & Whisnant, 2014; Seidel, Recker, Pimmer, & vom Brocke, 2014; Watson, Boudreau, Chen, & Sepúlveda, 2011; Watson, Boudreau, Li, & Levis, 2010). Executives like the CEO of c3 Energy identify information systems as a key to enabling sustainable energy systems[15]. The present paper adds to existing case knowledge via a quantitative empirical analysis examining the following research question: *How and to what degree do enterprise information systems impact organizational greenhouse gas emissions*? We examine this question by analyzing a unique data set combining surveys of corporate IS, GHG emissions, and environmental practices with other secondary sources that contain

15 http://www.businesswire.com/news/home/20150327005104/en/Thomas-Siebel-Addresses-Future-Grid-Wall-Street#.VUKCLiFViko

financial and environmental metrics. To the best of our knowledge, this is one of the first studies of its kind to have been conducted.

Our principal finding is that IS assets for enterprise support interact with firm GHG pollution reduction targets, altering whether or not those targets result in emissions reductions. Firms with the highest ratios of IS for enterprise support were associated with reduced GHG emissions when they had a reduction target. However, firms with lower ES ratios experienced the opposite effect and were associated with higher GHG emissions in the presence of reduction targets. Specifically, we find that if an average firm with a plan to reduce emissions and a ratio of ES physical scope packages set at the sample mean were to instead have their ES physical scope ratio increased by one standard deviation, *ceteris paribus* that firm would realize a decrease in GHG emissions of 712,164 metric tons of CO_2. This represents a 46.63% reduction in absolute emissions.

The rest of the chapter is organized as follows: we first review literature linking IS to firm performance and extend that to GHG emissions. We then identify studies that investigate the impact of non-IS management practices to GHG emissions to identify relevant practices that theory predicts IS will enable. We develop hypotheses to define how IS relates to these practices and present a conceptual model. We describe our data and variables of interest before estimating our model and presenting the results. We then conduct robustness checks, discuss limitations and future research before concluding.

Theoretical Background

In this section we review literature describing linkages between IS and firm performance, IS and GHG emissions, and management practices and GHG emissions.

IS Impacts on Firm Performance

Information systems in organizations perform three fundamental roles: they automate, informate, and can transform an organization's operations. Automating existing business processes replaces human labor, informating the business provides data to senior management and their employees across the organization, and transforming changes business processes and industry relationships in fundamental ways (Dehning, Richardson, & Zmud, 2003; Otim, Dow, Grover, & Wong, 2012; Zuboff, 1988). One of the ways that IS can transform an organization is by providing a platform for organizational integration, allowing disparate components of an organization (e.g. functions, business units, people and technology) to operate as a collective whole (Ranganathan & Brown, 2006).

A theory used widely to examine IS value impacts in an organization is the Resource Based View (RBV). RBV conceives of IS and their associated capabilities as a bundle of resources that, when valuable, rare, inimitable and non-substitutable, can lead to superior competitive performance (Liang, You, & Liu, 2010; Mata, Fuerst, & Barney, 1995; Melville, Kraemer, & Gurbaxani, 2004; Wade & Hulland, 2004). An example of an IT resource that leads to a sustainable competitive advantage would be managerial IT skills, which are socially complex, develop over long periods of time, are often tacit (cannot be written down), and causally ambiguous (Mata et al., 1995). This is in contrast to technical IT skills, which, while potentially a source of temporary competitive advantage, can quickly be overcome because the skills are highly mobile and can be acquired by firms relatively quickly through the labor market.

In addition to conceiving of IS as a monolithic resource, research examining the relationship between the IS resource and firm performance has also decomposed IS into specific assets and capabilities and estimated their varied performance influences (see Table 12). For example, Aral and Weill (2007) find that investments in informational IT assets (such as those for accounting and reporting) are associated with increased ROA, while IT practices, such as the use of IT for communication, interact with these assets leading firms with higher IT capabilities to enjoy greater profitability from their asset investments. Another conceptualization of IS is put forward by Ranganathan and Brown (2006) who conceive of enterprise resource planning (ERP) systems as platforms for integration, finding that financial markets reward investments in ERP systems with greater physical and functional scope.

Table 12. IS Business Value Conceptualization Examples

Paper	**Theoretic Lens**	**IS Construct**	**Categories of IS**	**Definitions**
(Aral & Weill, 2007)	Resource Based View (extension)	IT Assets and IT Capabilities	IT Assets: Infrastructure, Transactional, Informational, Strategic; IT Capabilities: Competences (Skills) and Practices (Routines)	Assets: Infra: foundation of shared services, Trans: automate processes, Info: Accounting, reporting, planning, Strategic: support market entry, product & service innovation; IT Capabilities: Practices: IT use for communication, Digital transaction intensity, Internet architecture; Skills: HR, IS Management
(Ranganathan & Brown, 2006)	Organization Integration and Option Value generation	ERP as IT infrastructure for integration and future growth as well as commitment signaling	Physical Scope of ERP and Functional Scope of ERP	Value Chain modules (materials management, operations, sales, and distribution) Enterprise Support modules (human resources, accounting, and finance)
(Benitez-Amado & Walczuch, 2012)	Resourced Based View, Dynamic Capabilities Theory, Natural Resource Based View	IT capability	IT Capability (one category), which includes both investment and management practices	Technological IT effort (0-10 scale based on investment in IT infrastructure (hardware & software) and IT management practices to improve operations efficiency

Recently, IS scholars have extended the conceptualization of value impacts to those in the natural environment (Benitez-Amado & Walczuch, 2012; Elliot, 2011; Watson, Boudreau, & Chen, 2010). Utilizing Hart's (1995) perspective that extends the RBV of the firm to a Natural Resource Based View (NRBV), one study examines the strategic outcomes of organizations' environmental decisions finding that IT capability enables environmental strategy, which also mediates IT's influence on firm performance (Benitez-Amado & Walczuch, 2012). Another perspective adopted by IS scholars proposes harnessing the transformative aspect of IS to increase energy efficiency (Rush & Melville, 2012; Watson, Boudreau, & Chen, 2010). In this paper, we examine the influence of information systems on firm greenhouse gas emissions, a measure of organizational performance that has an impact on the natural environment.

IS Impacts on Greenhouse Gas Emissions

Information Systems affect GHG emissions both directly and indirectly. Direct contribution, which is not the focus of this paper, arises from IT infrastructure, the physical component of IS. Such IT (datacenters, broadband networks, etc.) is estimated to consume 3% of the world's electricity, and through that consumption, contribute up to 3% of the world's GHG emissions (Ruth, 2009). Countering an upward trend in this consumption are advances in energy efficient IT products and practices, jointly known as "Green IT". Indeed, econometric research presents some evidence of ICT-enabled electricity reduction in manufacturing sectors, though not in service sectors (Cho et al., 2007; Collard et al., 2005).

In contrast, the focus of this study is on 'Green IS,' for which we adopt a definition from literature as referring "to practices which determine the investment in, deployment, use and management of information systems (IS) in order to minimize the negative environmental impacts of IS, business operations, and IS-enabled products and services"(Loeser, 2013). It is through these expanded business operations that much larger reductions of GHG emissions are made possible by the application of enterprise-wide GHG management and core business process improvement.

Green IS can affect emissions indirectly via two primary pathways. First, IS are essential to informating an organization by enabling measurement of its GHG impact across geographic and functional units, measurement that thus enables management. While an assumption of enterprise measurement and management is implicit in corporate and government policies to report and reduce GHG emissions (e.g. the Kyoto Protocol, Australia's NGER, the EU's emissions trading scheme, the US EPA's program to regulate CO2 as an air pollutant), success in IS deployment projects is not guaranteed (Markus & Robey, 2004; Nelson, 2007). In addition, even if the IS are successfully installed, there is no guarantee that their value objectives would be realized. The business value of IS literature demonstrates that not all companies are equally capable of realizing value objectives from IS. For instance, to see results, an IS needs to be actually used (Devaraj & Kohli, 2003), and the category of IS investment makes a difference in the type of value realized (Aral & Weill, 2007; Liang et al., 2010; Mithas et al., 2012). Value realization also relies on complementary investments in organizational resources, including IT exploitation capability (Aral & Weill, 2007), and it often takes time for an investment to yield its intended value (Brynjolfsson & Hitt, 2000; Melville et al., 2004).

The second pathway, Green IS, can indirectly affect emissions by transforming core business processes. One example of a (relatively) smaller impact transformation is the dematerialization of high carbon goods such as books to low carbon goods such as e-books. Dematerialization could save 500 metric tons of CO2 globally by 2020 (Raghupathi, Wu, & Raghupathi, 2014; Webb, 2008). Another example of business process change is reducing transport emissions by switching to video and teleworking, which could save 140M to 22M metric tons of CO2 annually by 2020 (Raghupathi et al., 2014).

Much larger scale reductions through IS-enabled transformation can potentially be achieved by using IS to improve logistics, creating IS-enabled smart electrical grids to manage demand and reduce unnecessary energy consumption, and automating lighting and ventilation systems in smart buildings. This combination could save over 5.23B metric tons of CO2e[16] by 2020 (Boudreau, Chen, & Huber, 2008; Raghupathi et al., 2014; The Economist, 2008; Watson, Boudreau, & Chen, 2010; Webb, 2008). This aggregate potential is promising, and case studies have cataloged early efforts in these areas (Seidel et al., 2014; Watson, Boudreau, Li, et al., 2010). However, beyond the carbon management systems described in earlier chapters, it is unknown which types of IS companies use to achieve emissions reductions, what scale of reductions they are achieving on average (if any) and how existing IS resources affect reductions. Further research is needed to understand which IT assets and capabilities are associated with enabling GHG reductions, as we now describe.

Other Literature Examining Organization's CO2 Emissions Output

While this is the first paper that we know of combining detailed IS and organizational data to examine their impact on GHG emissions, the impact of other

[16] CO2e is Carbon Dioxide equivalent and is a common measure to account for the differing warming potential of greenhouse gases. For the purposes of this paper, CO2e is shortened to CO2 for brevity.

organizational practices on GHG emissions is beginning to be examined in related management and industrial ecology disciplines. Some of these studies have utilized CDP data, identifying it as the largest, most comprehensive and complete collection of GHG management practices and emissions data available (Doda, Gennaioli, Gouldson, Grover, & Sullivan, 2015). In one study, up to 23 carbon management practices (CMP) extrapolated from the CDP survey did not explain in a statistically significant manner, year-to-year changes in a company's logged GHG emissions intensity. However, 2–3 specific practices were found to be marginally significant for various groups of companies (though these practices changed for each group) (Doda et al., 2015).

In another study, climate friendly management practices in manufacturing firms (such as GHG monitoring and targets) were found to lead to lower energy intensity and higher productivity using census data in the UK (Martin, Muûls, de Preux, & Wagner, 2012). In a third study, no relationship was found between management commitment (which was constructed from CDP responses) and GHG emissions using CDP data (Bettenhausen, Byrd, & Cooperman, 2014). In that study, the commitment measure included only monetary incentives, which were found in a fourth study to be associated with *increased* (worse) emissions, unless targeted at only the managers directly in charge of emissions performance (Eccles, Ioannou, Li, & Serafeim, 2013). Eccles et al. were able to explain 84.8% of the variation in the natural logarithm of a company's Scope 1 and 2 GHG emissions using firm scale, the presence of incentives, country, industry and year fixed effects, as well as firm fundamentals (e.g. gross profit margin, leverage ratio, capex to asset ratio). Their main finding is that non-monetary incentives can help emissions, while monetary incentives can hurt emissions (make them higher), unless those incentives are only awarded to the managers with direct responsibility for the firm's environmental performance.

Taken as a whole, the mixed results in the most relevant studies to our question are indicative of challenges for both organizations working to reduce GHGs and researchers. For organizations, these results indicate how difficult it may be for them to reduce their GHG emissions using the practices currently requested by shareholders and discussed in the literature. For researchers, it is difficult to make the reported data (the best available) comparable, and much cleaning and controlling is required. Eccles et al. were able to demonstrate the effect of incentives only after including extensive industry, sector and sub-sector controls, and even then the practices had to be targeted at the correct levels of management to yield results. We thus judge the effect of management practices to be not completely settled and begin hypothesizing conservatively. As part of this conservatism, we recognize that various external pressures can lead organizations to adopt certain management practices (Reid & Toffel, 2009), and that emissions performance can lead to financial performance (Hoffman, 2005). We thus include these two items in our conceptual model, but exclude them from our hypothesizing, measurement, and testing so that we may focus our attention on the role IS has in moderating the relationship between management practices and GHG emissions performance.

This chapter advances efforts to quantify the impact of IS on GHG emissions by directly examining an IS resource's impact on GHG emissions output while accounting for important organizational complements such as sustainability orientation, goals and practices. In this way, we build on prior IS literature that has established the important yet complex interactions between IS and organizational complements necessary to generating value, while advancing new knowledge by examining new complements, a new context, and a new dimension of value. Specifically, we test pathways from IS to firm value identified in the literature to determine their impact on this new dimension of firm performance, utilizing detailed firm-level IS data. By doing so, we provide a unique empirical quantification of the impact of enterprise IS resources on GHG emissions.

Hypothesis Development

Sustainability Commitment and Management Practices

It is unlikely that an organization will achieve superior GHG performance without first being committed to that end. A sustainability commitment could result from either management emphasis on specific sustainability-oriented practices, or if firms have naturally built their business operations with a sustainability orientation, effectively embedding the firm's commitment to sustainability into its standard business practice and decision-making calculus at all levels of the organization. In the case of management emphasis, executives can signal their general commitment to the management of GHG through pursuing a range of specific practices and incorporating their commitment into the organization's business processes and communications to employees and external stakeholders (Bettenhausen et al., 2014; Eccles et al., 2013; Martin et al., 2012). Such executive-led practices could either substitute for or complement a firm's sustainability orientation with either mechanism potentially resulting in superior GHG performance. If a firm has already achieved such an orientation, we would expect it to be externally observable (e.g. to ratings agencies that issue environmental ratings for a firm such as those investigated by Lyon and Shimshack (2012)), as well as predict the adoption of CO_2 management practices.

One direct practice associated with emissions reductions in recent literature is setting a CO_2 reduction target (Bettenhausen et al., 2014). Such a target quantifies leadership commitment and defines an observable success measure to coordinate organizational efforts. Some evidence indicates that making reduction commitments can result in GHG emissions reductions for some sectors (Doda et al., 2015). For IS informating capabilities to enhance coordination and its outcomes, the impetus for that coordination must exist in the first place. We believe commitment to sustainability thus represents the highest-level predictor of an organization's GHG emissions performance, leading to our first hypothesis:

H1a: *GHG emissions reduction targets in organizations will be associated with reduced overall GHG emissions (improved environmental performance).*

At this time, we have no reason to believe that management practices would affect Scope 1 (direct) and Scope 2 (purchased energy) emissions differently. Thus, in the following secondary hypotheses we propose the same relationship as predicted overall.

H1b: *GHG emissions reduction targets in organizations will be associated with reduced Scope 1 GHG emissions (improved environmental performance).*

H1c: *GHG emissions reduction targets in organizations will be associated with reduced Scope 2 GHG emissions (improved environmental performance).*

Information Systems Resources

ERP systems are large, integrated suites of applications with modules to support many if not all administrative functions or value chain activity in a firm (Hayes, Hunton, & Reck, 2001). Because of their cost, not all firms install all modules, but those that install more functionality in more locations can realize greater organizational integration whose benefits are valued by shareholders (Ranganathan & Brown, 2006). Given ERP's reach and impact on the core operations of large companies, we adopt measures from the enterprise systems literature to explore the relationship between IS, a firm's emissions reduction targets and its emissions performance.

In our conceptualization, ERP implementations are IS resources that can both automate and informate the firm through its enterprise support modules, as well as automate and transform the firm via value-chain modules. Similar to prior studies, we decompose the IS resource into assets and capabilities, but unlike prior studies that utilize IT budgets to quantify the extent of an IS asset (e.g. (Aral & Weill, 2007)), we instead focus on the physical extent and the functional nature of the ERP installation within an organization to represent its IS assets and capabilities. By focusing on specific functions of existing IS we can better specify the linkage between that asset or capability and the GHG emissions outcome with which we are concerned.

Literature leads us to expect the physical scope of the ERP implementations to influence realized value due to organizational integration across sites (Ranganathan & Brown, 2006). We characterize this physical scope as a measure of IS assets present in an organization because as ERP modules are installed at more sites, IS achieves a greater reach and is available to more of the organization. If IS assets are uniformly valuable to integrating organizations and reducing their GHG emissions, then any ERP module of greater physical scope could be expected to increase firm integration and enable it to meet its emissions objectives. As we have no indication that IS assets would influence Scope 1 and Scope 2 emissions differently, we can formally state the expected impact of physical scope as:

H2a: *IS assets of greater physical scope will interact with a firm's emissions reduction targets to moderate their impact on its overall GHG reductions.*

H2b: *IS assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its Scope 1 GHG reductions.*

H2c: *IS assets of greater physical scope will interact with a firm's emissions reduction targets to moderate their impact on its Scope 2 GHG reductions.*

We next examine the functional scope of ERP implementations within an organization as the dimension of relevance for a firm's IS capability. Organizations with ERP implementations of greater functional scope have incorporated IS into more of their business processes. This has created more opportunities for multiple functional areas to work together to coordinate their responses to management emissions reduction targets via software than organizations with lesser functional scope. Measuring how prevalent ERP systems with greater functional scope are within an organization thus represents how widespread the cross-functional capability to use the assets discussed above has become. ERP implementations with greater functional scope have been theorized to enable greater organization integration and have been shown to yield greater business value than ERP implementations with lesser scope (Ranganathan & Brown, 2006). We thus hypothesize:

H3a: *IS capability indicated by greater functional scope will interact with a firm's emission reduction targets to moderate their impact of on its overall GHG reductions.*

H3b: *IS capability indicated by greater functional scope will interact with a firm's emission reduction targets to moderate their impact of on its Scope 1 GHG reductions.*

H3c: *IS capability indicated by greater functional scope will interact with a firm's emission reduction targets to moderate their impact of on its Scope 2 GHG reductions.*

Given the various constructs and value pathways examined in IS research, a key question addressed in our study is *which* IS assets are most relevant to reducing GHG emissions. Are assets that informate the firm most important in mediating the ability of management to make good on its commitment to environmental sustainability? Perhaps experience transforming the firm with IS for strategic and value-chain activities is of greater importance?

To investigate these questions, we further categorize IS assets of greater physical scope into enterprise support packages and value chain packages, according to their purpose and role in the organization. Enterprise support (ES) packages such as Accounting, Financial, and Human Resources modules informate large, distributed organizations utilizing IT infrastructure and software created to facilitate information capture, storage and exchange information. Such software disseminates management goals, commitments, and incentive structures to workers (informating down), and also provides information about progress toward those goals from the workers and managers involved in the change (informating up) (Dehning et al., 2003). We expect managers experienced with ES to leverage existing IS assets to achieve superior emissions management. This expectation arises from the similarities between software-mediated management of distributed accounting, financial, and HR functions and the complexities of capturing and measuring emissions activity. Emissions must be captured accurately, verifiably, and in a timely enough fashion to use that data for managerial and incentive purposes. However, absent management commitment to sustainability and the presence of emissions management practices, existing IS assets for enterprise support are not anticipated to impact emissions performance. We thus hypothesize:

H4a: *Enterprise Support assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its overall GHG reductions.*

H4b: *Enterprise Support assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its Scope 1 GHG reductions.*

H4c: *Enterprise Support assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its Scope 2 GHG reductions.*

In comparison, ERP modules to transform the business processes that are core to a company's value chain (VC) may moderate how sustainability management practices affect GHG emissions via different pathwaysg. Firms have adopted VC-supporting IS for product procurement and supply chain management, manufacturing and resource planning, as well as sales and customer support. Much as with ES deployment, the experience of transforming core VC processes using IS assets is likely to lead firms to utilize their existing IS to implement new practices that management adopts to improve emissions performance. The more widespread VC modules are deployed as an asset, the more areas of a firm are able to respond to those new management goals utilizing existing software to alter their operations, material management, sales, and distribution business processes. Unlike ES modules, however, widespread physical implementation of these VC modules may also indicate the widespread adoption of complementary business logic to reduce waste and its associated costs (e.g. lean manufacturing or six sigma), yielding greater efficiencies and resulting in less pollution when that is a management priority. We thus hypothesize:

H5a: *Value Chain assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its overall GHG reductions.*

H5b: *Value Chain assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its Scope 1 GHG reductions.*

H5c: *Value Chain assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its Scope 2 GHG reductions.*

The conceptual model with a measurement boundary is summarized in Figure 5 and hypotheses are presented in Table 13.

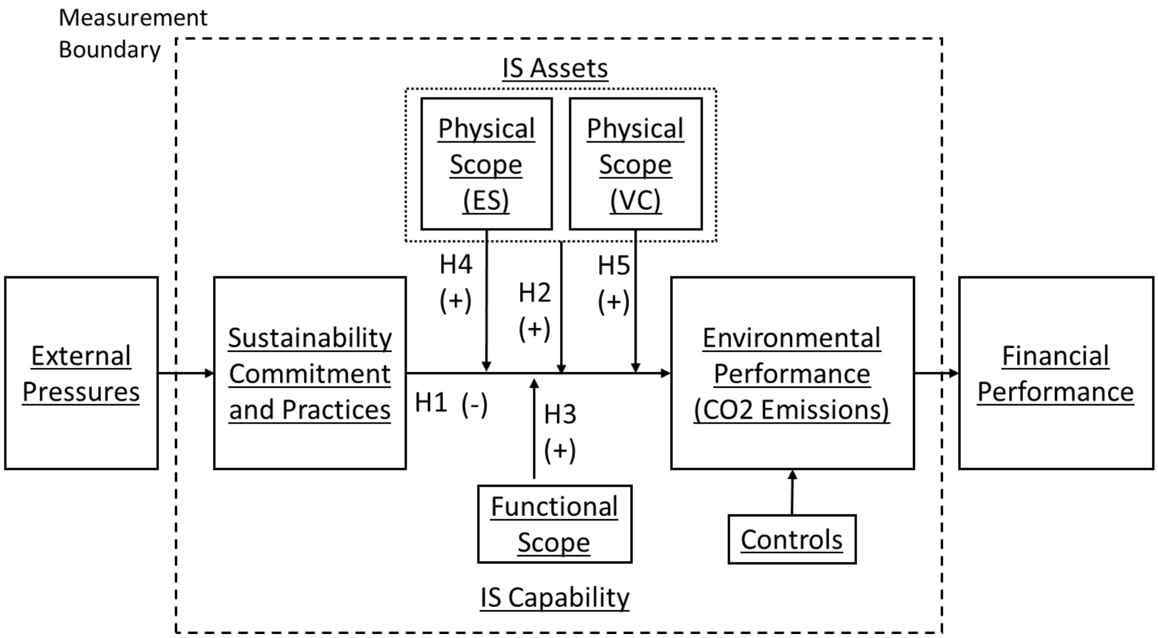


Figure 5. Conceptual Model

Measures for IS Capability and Assets adapted from Ranganathan and Brown (2006).

Table 13. Hypothesized Relationships

#	Sign	Hypothesis
H1a:	-	GHG emissions reduction targets in organizations will be associated with reduced overall GHG emissions (improved environmental performance).
H1b:	-	GHG emissions reduction targets in organizations will be associated with reduced Scope 1 GHG emissions (improved environmental performance).
H1c:	-	GHG emissions reduction targets in organizations will be associated with reduced Scope 2 GHG emissions (improved environmental performance).
H2a:	+	IS assets of greater physical scope will interact with a firm's emissions reduction targets to moderate their impact on its overall GHG reductions.
H2b:	+	IS assets of greater physical scope will interact with a firm's emissions reduction targets to moderate their impact on its Scope 1 GHG reductions.
H2c:	+	IS assets of greater physical scope will interact with a firm's emissions reduction targets to moderate their impact on its Scope 2 GHG reductions.
H3a:	+	IS capability indicated by greater functional scope will interact with a firm's emission reduction targets to moderate their impact of on its overall GHG reductions.
H3b:	+	IS capability indicated by greater functional scope will interact with a firm's emission reduction targets to moderate their impact of on its Scope 1 GHG reductions.
H3c:	+	IS capability indicated by greater functional scope will interact with a firm's emission reduction targets to moderate their impact of on its Scope 2 GHG reductions.
H4a:	+	Enterprise Support assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its overall GHG reductions.

#	Sign	Hypothesis
H4b:	+	Enterprise Support assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its Scope 1 GHG reductions.
H4c:	+	Enterprise Support assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its Scope 2 GHG reductions.
H5a:	+	Value Chain assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its overall GHG reductions.
H5b:	+	Value Chain assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its Scope 1 GHG reductions.
H5c:	+	Value Chain assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its Scope 2 GHG reductions.

Research Methodology

Data

The population for our study is large global firms with a presence in North America. Data on environmental, IT, and financial dimensions are gathered from secondary sources including CDP, Harte Hanks, and Compustat, respectively.

First, environmental commitment and performance measures are collected from CDP (formerly known as the Carbon Disclosure Project) and the Asset4 database. CDP conducts an annual survey of the world's largest firms on behalf of institutional investors seeking to understand the impact on the value of their investment from factors connected to climate change such as regulation, taxation, technological innovation, shifts in consumer attitudes and demand, and changes in the climate system. Greenhouse gas emissions are directly requested, as are details related to projected risks, risk management, and projected opportunities. The data in this paper are drawn from the surveys conducted by CDP in the years 2007–2010. The letter accompanying the 2007 survey states that the questionnaire was on behalf of institutional investors whose collective assets under management were in excess of $41 trillion USD, that it was sent to 2,400 of the world's largest companies, and that in the prior year 72% of the FT500 responded. In the 2008 survey, the number of companies requested increased to 2,800 and the response rate for 2007 was noted as over 1,300. Each subsequent year more companies were contacted and more responders were incorporated into the database. Responders are given the option to report historical data, as well as the option to not make the data public (which, if exercised would have excluded it from the data set available to us, though not from the summary reports and response statistics issued by CDP). Finally, as mentioned earlier, CDP data have been employed in related literature (Doda et al., 2015; Reid & Toffel, 2009).

Second, IS data are gathered from the firm Harte Hanks, which conducts detailed IT surveys of North American and European company operations, though we limit our investigation to North American sites at this time. In addition to enterprise-level information on IT employees, infrastructure, and vendors there are also detailed breakdowns of enterprise software and its deployment to the company's various sites, the number of users of that software, and the number of employees in each business function that are at the site. This database has been used in prior IS studies (e.g. (Chen & Forman, 2006)).

Third, annual financial data are collected from Compustat. The data are then linked using identifiers common to each data set, or when such identifiers were not available, using name matching. In this preliminary analysis, firms that cannot be matched across data sets one-to-one (e.g. because of mergers and acquisitions, divestitures, ownership structure) are excluded from the analysis, as are firms for which all necessary data variables defined below were not available for the appropriate year.

Variable Definition

The dependent variable of our study, CO2 emissions, is nascent in the IS literature as a measure of firm performance. We thus build on studies in other management fields that analyze the association between organizational practices and CO2 emissions performance (Bettenhausen et al., 2014; Eccles et al., 2013). Consistent with this literature, we choose to focus on only the first two of three CO2 emission scopes defined by the GHG protocol[17]: Scope 1 (all direct emissions, such as stationary and mobile combustion) and Scope 2 (all indirect emissions from the consumption of purchased energy including electricity, heat, or steam). These first two scopes are considered more reliable and less subject to measurement variation when compared with Scope 3 (other indirect emissions such as supply chain emissions). Consistent with other literature that uses the pooled cross sectional OLS regression that we adopt, the measure is constructed by summing Scope 1 and Scope 2 emissions and calculating the natural logarithm of this sum. While our main analysis utilizes this natural logarithm, we also attempted a robustness check using the change in this measure from one year to the next. This change in logged scope 1 and scope 2 emissions has also been used in studies of CO2 emissions performance (Doda et al., 2015).

Next, we include controls for those factors that are likely to be associated with CO2 performance. These include third-party environmental ratings (Lyon & Shimshack, 2012), employee incentives for CO2 performance, and controls for country (which may differ because of environmental regulations), industry (based on the GICs 10 sector classifications), year, size, and production volume (operationalized as cost of goods sold in thousands of dollars per employee). We operationalized a company's sustainability

[17] http://www.ghgprotocol.org/calculation-tools/faq

orientation using the “Environmental Pillar” score from the Asset4 database (accessed via DataStream). A firm’s commitment to reducing emissions was operationalized as a binary variable derived from the CDP survey where respondents indicated whether their firm had an emissions reduction target. For the size control, we operationalized this with indicator variables for categories of annual firm revenue similar to Mithas et al. (2012).

Enterprise IS classifications are obtained from the literature and applied to the enterprise application modules identified at each site in the detailed IT survey conducted by Harte Hanks. We followed Ranganathan and Brown’s (2006) measure of a firm’s IS Resources using a two-point scale (measured at the module level instead of at the announcement level) for whether an ERP installation was of greater or lesser physical scope. A module is considered to be of greater physical scope when it is deployed to more than one site within the same company, and of lesser physical scope when it is only deployed at a single site. We also adopt their definition of “greater functional scope,” though we measure this at the site level (instead of at the announcement level). A greater functional scope is defined as either having a full suite ERP installed (e.g. SAP R/3, SSA, ERPLN), or 2+ value chain modules of an ERP. Value-chain modules perform core procurement, manufacturing and sales functions (e.g. CRM, Supply Chain, MRP modules). A lesser functional scope is defined as 0-1 value chain modules and 1 or more Enterprise Support modules (e.g. HR, Accounting, Finance modules). These measures are then aggregated to the corporate level using the following calculations: Greater ERP Functionality Proportion (coded as GrtFcnProp1) is the quotient of a count of sites with Greater Functionality (Full ERP or 2+ VC modules) divided by the total number of a firm’s total sites in that year. Physical Scope measures (Overall, VC and ES, coded as

GrtPhysBoth, GrtPhysVCF, and GrtPhysES respectively) are ratios of counts of the relevant packages that span multiple sites divided by the number of total sites.[18]

These calculations result in two primary measures of IS resources (one for assets and one for capabilities), and two sub-measures of IS assets. These measures and their operationalization are summarized in

[18] For example, if a company has 4 sites, 3 of which have a particular HR module from an ERP vendor, 2 with Accounting, 2 with CRM, 1 with Materials Management and 1 with Finance, the Overall physical scope ratio would be 3/4 = .75, the ES ratio would be 2/4 = .5 and the VC ratio would be 1/4=.25. This is because HR and Accounting are ES modules with greater physical scope and CRM is a VC module with greater physical scope.

Table 14. Descriptive statistics for these and other variables are presented in Table 15. All IS variables are lagged by one year, so that they represent the functional and physical scope of the indicated ERP systems in the year prior to the measured emissions. This is consistent with prior literature that has found lags between measurement of IS and their performance impacts (Aral & Weill, 2007; Brynjolfsson & Hitt, 2000; Devaraj & Kohli, 2003). Correlations between the variables are shown in Table 16. Of note is the high correlation (.707) between GrtFcnProp1 (the proportion of Greater ERP Functionality) and GrtPhysVCF (Value Chain Physical Scope). This could indicate a potential issue with the measure, which we will return to in the robustness and limitations sections.

Table 14. Construct Operationalization

Construct	Variable Name (code)	Variable Construction / Definition	Source
Environmental Performance	CO2 emissions: Scope 1 + Scope 2 (lnScope12)	Natural log of the sum of Scope 1 (direct) and Scope 2 (indirect purchased energy) CO_2 emissions	CDP
Sustainability Commitment and Practices	Environmental Orientation (EnvScore)	Environmental Orientation. Operationalized as the "Environmental Pillar" score assigned by the third party rating firm ASSET4. This score is constructed from 10 weighted factors that aggregate 70 KPIs (each individually weighted per 52 industry classifications)[19]. 13% of the ranking comes from emissions reduction policies and practices (the other are product innovation and resource reduction) and 25% of the weighting comes from emission reduction tonnes/revenue metrics. The balance of the weighting is from involvement in controversies, leadership, and resource reduction metrics.	ASSET4
Sustainability Commitment and Practices	Reduction Target (ReductionPlanBin)	Reduction Goal. Yes/No (coded 1/0) in response to "Do you have a current emissions reduction target?" (2009 survey wording, other years similar)	CDP
Sustainability Commitment and Practices	Incentive (IncentiveBin)	Presence of Incentives. Yes/No (coded 1/0) in response to "Do you provide incentives for individual management of climate change issues including attainment of GHG targets?" (2009 wording for both questions, other years similar)	CDP
IS Asset	Physical Scope (GrtPhysBoth)	Ratio of sum of Value Chain (VC) and Enterprise Support (ES) modules with greater physical scope (installed at more than 1 site) to total number of sites. IS asset measures constructed by a three step process. First, modules are identified by their manufacturer and function and classified into either value chain (VC), enterprise support (ES) or other. Second, a count is made of how many of these modules are of Greater Physical Scope, that is are present at more than one site within the company that year. Third, this count is divided by the number of sites in the company, creating a ratio of modules with greater physical scope over the total number of sites at a company	Harte Hanks
IS Asset	Value Chain Physical Scope (GrtPhysVCF)	Ratio of Value Chain (VC) modules with greater physical scope (installed at more than 1 site) to total number of sites. VC modules perform core procurement, manufacturing and sales functions (e.g. CRM, Supply Chain, MRP). Other than module classification, the IS asset sub-measure is constructed as described above	Harte Hanks
IS Asset	Enterprise Support Physical Scope (GrtPhysES)	Ratio of Enterprise Support (ES) modules with greater physical scope (installed at more than 1 site) to total number of sites. ES modules facilitate corporate administration by providing information about corporate performance, goals, and incentives to managers and employees (e.g. HR, Accounting, Finance modules). Other than module classification, the IS asset sub-measure is constructed as described above.	Harte Hanks

[19] Text description of methodology at http://thomsonreuters.com/content/dam/openweb/documents/pdf/tr-com-financial/methodology/corporate-responsibility-ratings.pdf
Weights and KPIS available at http://www.trcri.com/images/pdf/Environmental_KPI_Weights.xlsx

Construct	Variable Name (code)	Variable Construction / Definition	Source
IS Capability	Greater ERP Functionality (GrtFcnProp1)	Proportion of sites with Greater ERP Functionality. Constructed by first counting the number of sites with greater functionality, which is defined as having a Full ERP system (e.g. SAP R/#) or 2+ VC modules installed at the site. This count is then divided by the total number of sites.	Harte Hanks
Control	Size1-Size4	Firm size dummy variables (based gross annual sales in millions of US dollars) Size1: Sales < $5B, Size2: $5B-10B, Size3: $10B-25B, Size4: > $25B	COMPU STAT
Control	COGS – in thousands of USD per employee (Empcogs)	COGS (thousands of USD per employee). Used to control for variability in input	COMPU STAT
Control	Industry (Ind: sector name)	Firms are classified using indicator variables at the sector level of the Global Industry Classification Standard (GICS).	CDP
Control	Country (Cnt: Country name)	Indicator variables used to identify if the company is headquartered in the USA, Canada or United Kingdom.	CDP
Control	Year (Yrxxxx)	Indicator variables for year 2005-2009	

Table 15. Firm Descriptive Statistics

Variable (code) n=127	mean	sd	median	min	max	sum of indicators
Untransformed CO2 emissions: Scope 1 + 2 (Not utilized in model)	10,390,150	26,016,580	1,327,272	3	207,799,000	NA
Untransformed Sales: gross annual sales in millions of US dollars (Not utilized in model)	18,502.3	23,272.4	10,414.5	118.5	124,936.0	NA
CO2 emissions (lnScope12)	14.069	2.562	14.099	1.099	19.152	NA
Environmental Orientation (EnvScore)	71.889	23.17	78.86	11.48	96.65	NA
Reduction Goal[20] (ReductionPlanBin)	0.74	0.44	1	0	1	94
Incentive[21] (IncentiveBin)	0.551	0.499	1	0	1	70
Physical Scope (GrtPhysBoth)	0.051	0.075	0.022	0	0.333	NA
Greater ERP Functionality Proportion* (GrtFcnProp1)	0.076	0.159	0	0	1	NA
Value Chain Physical Scope Ratio* (GrtPhysVCF)	0.028	0.068	0	0	0.333	NA
Enterprise Support Physical Scope Ratio* (GrtPhysES)	0.023	0.038	0	0	0.25	NA
COGS – in thousands of USD per employee (Empcogs)	0.522	0.549	0.271	0.012	2.345	NA

[20] Yes/No (coded 1/0) in response to “Do you have a current emissions reduction target?”

[21] Yes/No in response to “Do you provide incentives for individual management of climate change issues including attainment of GHG targets?” (2009 wording for both questions, other years similar)

Variable (code) n=127	**mean**	**sd**	**median**	**min**	**max**	**sum of indicators**
Indicator Control Variables						
Size1: Sales < $5B	0.228	0.421	0	0	1	29
Size2: Sales $5B-10B	0.354	0.48	0	0	1	45
Size3: Sales $10B-25B	0.189	0.393	0	0	1	24
Size4: Sales > $25B	0.228	0.421	0	0	1	29
Ind: Consumer Discretionary	0.047	0.213	0	0	1	6
Ind: Consumer Staples	0.157	0.366	0	0	1	20
Ind: Energy	0.15	0.358	0	0	1	19
Ind: Financials	0.079	0.27	0	0	1	10
Ind: Health Care	0.118	0.324	0	0	1	15
Ind: Industrials	0.079	0.27	0	0	1	10
Ind: Information Technology	0.079	0.27	0	0	1	10
Ind: Materials	0.142	0.35	0	0	1	18
Ind: Utilities	0.15	0.358	0	0	1	19
Cnt: USA	0.945	0.229	1	0	1	120
Cnt: Canada	0.016	0.125	0	0	1	2
Cnt: United Kingdom	0.039	0.195	0	0	1	5
Yr2005	0.016	0.125	0	0	1	2
Yr2006	0.157	0.366	0	0	1	20
Yr2007	0.323	0.469	0	0	1	41
Yr2008	0.402	0.492	0	0	1	51
Yr2009	0.102	0.304	0	0	1	13
* All IS measures are lagged and represent IS the year before emissions and other measures						

Table 16. Correlations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1. lnScope12	1																					
2. EnvScore	0.304 ***	1																				
3. Reduction PlanBin	0.220 *	0.274 **	1																			
4. IncentiveBin	0.184 *	0.036	0.260 **	1																		
5. GrtPhysBoth	(0.102)	(0.076)	(0.011)	0.107	1																	
6. GrtFcnProp1	(0.224)*	(0.073)	0.017	0.162 ~	0.601 ***	1																
7. GrtPhysVCF	(0.143)	(0.117)	0.004	0.175 *	0.859 ***	0.707 ***	1															
8. GrtPhysES	0.056	0.059	(0.030)	(0.103)	0.415 ***	(0.088)	(0.108)	1														
9. Empcogs	0.182 *	(0.049)	(0.130)	(0.206)*	0.015	(0.053)	0.029	(0.022)	1													
10. Size2_5B 10B	0.295 ***	0.052	(0.049)	0.040	0.034	(0.206)*	(0.119)	0.277 **	(0.053)	1												
11. Size3_10B 25B	0.152 ~	0.213 *	0.148 ~	0.072	(0.042)	(0.054)	(0.027)	(0.033)	0.354 ***	(0.358)***	1											
12. Size4_25B	(0.003)	(0.214)*	(0.063)	(0.037)	0.047	0.164 ~	0.109	(0.104)	(0.079)	(0.403)***	(0.263)**	1										
13. Ind: Consumer Staples	(0.131)	(0.167)~	0.158 ~	0.303 ***	0.106	0.053	0.142	(0.047)	(0.184)*	(0.004)	(0.209)*	0.125	1									
14. Ind: Energy	0.062	(0.113)	(0.104)	(0.110)	(0.058)	(0.028)	0.022	(0.152)~	0.409 ***	(0.080)	0.249 **	(0.070)	(0.181)*	1								
15. Ind: Financials	(0.302)***	(0.043)	(0.293)***	(0.265)**	(0.155)~	(0.139)	(0.118)	(0.090)	0.038	(0.033)	(0.141)	(0.020)	(0.126)	(0.123)	1							
16. Ind: Health Care	(0.298)***	(0.069)	0.050	0.085	0.268 **	0.365 ***	0.327 ***	(0.059)	(0.031)	(0.220)*	0.260 **	(0.025)	(0.158)~	(0.153)~	(0.107)	1						
17. Ind: Industrials	0.068	0.041	0.107	(0.030)	0.023	(0.092)	(0.033)	0.104	(0.164)~	0.211 *	0.008	(0.089)	(0.126)	(0.123)	(0.085)	(0.107)	1					
18. Ind: Information Technology	(0.176)*	0.065	0.040	0.029	(0.077)	0.211 *	(0.120)	0.063	(0.168)~	(0.155)~	0.008	(0.020)	(0.126)	(0.123)	(0.085)	(0.107)	(0.085)	1				
19. Ind: Materials	0.270 **	0.178 *	(0.017)	(0.042)	(0.022)	(0.120)	(0.090)	0.119	(0.171)~	0.077	(0.023)	0.048	(0.176)*	(0.170)~	(0.119)	(0.149)~	(0.119)	(0.119)	1			
20. Ind: Utilities	0.451 ***	0.161 ~	0.047	(0.021)	(0.073)	(0.169)~	(0.141)	0.110	0.278 **	0.151 ~	(0.202)*	0.087	(0.181)*	(0.176)*	(0.123)	(0.153)~	(0.123)	(0.123)	(0.170)~	1		
21. Cnt: Canada	(0.031)	(0.004)	(0.069)	(0.140)	(0.086)	(0.060)	(0.052)	(0.075)	(0.090)	(0.094)	(0.061)	(0.069)	(0.055)	(0.053)	(0.037)	(0.046)	(0.037)	(0.037)	0.311 ***	(0.053)	1	
22. Cnt: UK	(0.012)	0.100	(0.065)	(0.143)	(0.074)	(0.093)	(0.083)	0.004	(0.115)	(0.150)~	0.213 *	(0.110)	(0.088)	0.029	0.091	(0.074)	(0.059)	(0.059)	0.266 **	(0.085)	(0.026)	1
Indicator variables for years omitted for space																						

Estimation Model

We estimate the relationship between CO2 emissions and the independent variables using pooled cross-sectional OLS. The full model with interactions can be written as

$$lnScope12 = \beta_0 + \beta_1 EnvScore + \beta_2 ReductionPlanBin + \beta_3 IncentiveBin + \beta_4 GrtFcnProp + \beta_5 PhysScope + \beta_6 (ReductionPlanBin * GrtFcnProp) + \beta_7 (ReductionPlanBin * PhysScope) + \beta_c' X_c + \epsilon$$

where X_c is a vector of control variables to capture year, industry and country fixed effects as well as control for production input variation. For the model with disaggregated IS assets, $\beta_5 PhysScope$ is replaced with $\beta_5 GrtPhysVCF + \beta_6 GrtPhysES$ and each term is interacted with $ReductionPlanBin$.

Results and Discussion

Before estimating the complete model, a preliminary regression without the IS variables or their interactions is estimated and the results are presented in panel A of Table 17. We then introduce the aggregate IS asset variable and capability variable described above and present the results in Panel B. Finally, we interact the IS variables with the emissions reduction target indicator and perform a final regression. These results are presented in Panel C.

First, in panel A, there is some indication that reduction targets and incentives are associated with CO2 emissions (p-values = .075 and .059 respectively), however the sign of the coefficients is in the opposite direction from what was hypothesized, provisionally indicating these practices may not be associated, on average and controlling for the covariates in our model, with lower emissions. We next introduce the IS variables to observe how this affects the estimation.

Table 17. OLS Regression Estimates of Aggregate Asset and Capability Effects on Total CO2 Emissions

Variable	A. Environmental Practices	B. IS direct effect	C. Interaction Model (2nd parenthesis is p-value)
Intercept	10.977*** (1.334)	11.088*** (1.343)	10.812*** (1.348) (0)
Environmental Orientation	0.006 (0.007)	0.006 (0.007)	0.004 (0.008) (0.57)
Reduction Target	0.705~ (0.392)	0.675~ (0.396)	0.849~ (0.475) (0.077)
Incentives	0.668~ (0.35)	0.616~ (0.359)	0.761* (0.367) (0.041)
Greater ERP Functionality		1.418 (1.388)	-2.971 (3.079) (0.337)
Physical Scope (Greater VC + ES)		-2.596 (2.629)	5.028 (5.406) (0.355)
Controls			
Size (Sales $5B-$10B)	1.993*** (0.452)	2.08*** (0.461)	2.081*** (0.465) (0)
Size (Sales $10B-$25B)	3.201*** (0.598)	3.337*** (0.63)	3.264*** (0.633) (0)
Size (Sales > $25B)	1.308** (0.473)	1.263** (0.478)	1.384** (0.488) (0.006)
COGS	-0.39 (0.4)	-0.417 (0.41)	-0.4 (0.408) (0.33)
Ind: Consumer Staples	1.257 (0.853)	1.347 (0.86)	1.267 (0.857) (0.143)
Ind: Energy	2.293** (0.843)	2.278** (0.847)	2.327** (0.844) (0.007)
Ind: Financials	0.81 (0.941)	0.852 (0.955)	0.986 (0.961) (0.308)
Ind: Health Care	-0.465 (0.829)	-0.528 (0.856)	-0.345 (0.858) (0.689)
Ind: Industrials	1.782* (0.875)	1.856* (0.881)	1.931* (0.878) (0.03)
Ind: Information Technology	0.687 (0.89)	0.526 (0.905)	0.287 (0.913) (0.754)
Ind: Materials	3.626*** (0.879)	3.728*** (0.887)	3.686*** (0.884) (0)
Ind: Utilities	4.915*** (0.924)	5.027*** (0.943)	4.913*** (0.941) (0)
Country Fixed Effects	All neg and N.S.	All neg and N.S.	All neg and N.S.
Year Fixed Effects	All neg and N.S.	All neg and N.S.	All neg and N.S.
Reduc. Target x Functional Scope			5.294 (3.317) (0.114)
Reduction Target x Phys. Scope			-10.181 (6.423) (0.116)
Adj. R^2 (Overall)	0.606	0.603	0.607
F-Stat (degrees of freedom)	10.238*** (21 , 105)	9.338 *** (23 , 103)	8.796*** (25 ,1019)
Observations	127	127	127
Number of Firms	62	62	62

***, **, *, ~ indicate significance at the .001, .01, .05 and .1 levels. (Standard Errors in parentheses). All coefficients relative to effect on ln(CO2) a US firm in the Consumer Discretionary industry with sales < 5 billion USD, reporting for 2005

The sign and significance of these environmental practices remains the same in panel B when the IS variables are introduced, though their p-values rise to .09. Neither aggregate IS assets (physical scope) or IS capabilities (Greater ERP functional scope) is significant in this step of the modeling, with p-values of .309 and .326, respectively.

In panel C, after interacting the two measures of IS with the reduction target variable, reduction target is marginally significant (p=.077) and Incentives are significant at the 5% level (p=.041). The signs on these variables is still both positive, and so there is no support thus far H1a. The interactions of reduction target with the two IS variables are both insignificant (p = .114 and p=.116). We can conclude from these results that hypothesis H2a and H3a are not supported. These results, taken together with the sign on the incentive and reduction targets coefficients indicating that these practices are positively associated with CO_2 emissions rather than negatively associated with them, presents a puzzle, motivating us to investigate further.

The next model's base specification is identical to the previous specification, so its results are re-presented for convenience in panel A of Table 18. In panel B, we introduce the change in the model by using the disaggregated IS asset measures for enterprise support of greater physical scope and value chain of greater physical scope. We again use the same measure of IS capability as before. Finally, in panel C we present the results of the model with reduction targets fully interacted with the IS measures.

The results in panel A are as before, with some evidence of reduction plans and incentives having a positive sign and being marginally significant. When the disaggregated IS variables are introduced, the sign of these environmental practices remains the same in panel B though they are no longer significant at the 10% level. Of the IS variables in panel B, only the Enterprise Support Physical Scope measure is marginally significant (p = .077).

Table 18. OLS Regression Estimates of Disaggregated IS Asset and Capability Effects on Total CO2 Emissions

Variable	A. Environmental Practices	B. IS direct effect	C. Interaction Model
Intercept	10.977*** (1.334)	11.012*** (1.336)	10.68*** (1.318)
Environmental Orientation	0.006 (0.007)	0.005 (0.007)	0.008 (0.008)
Reduction Target	0.705~ (0.392)	0.643 (0.394)	1.126* (0.483)
Incentives	0.668~ (0.35)	0.521 (0.363)	0.668~ (0.364)
Greater ERP Functionality		0.479 (1.516)	-1.565 (3.283)
Value Chain Physical Scope		0.38 (3.287)	2.115 (6.485)
Enterprise Support Physical Scope		-7.393~ (4.143)	5.954 (6.583)
Controls			
Size (Sales $5B-$10B)	1.993*** (0.452)	2.213*** (0.466)	2.187*** (0.461)
Size (Sales $10B-$25B)	3.201*** (0.598)	3.462*** (0.631)	3.352*** (0.623)
Size (Sales > $25B)	1.308** (0.473)	1.28** (0.475)	1.481** (0.478)
COGS	-0.39 (0.4)	-0.48 (0.409)	-0.449 (0.401)
Ind: Consumer Staples	1.257 (0.853)	1.425~ (0.856)	1.344 (0.838)
Ind: Energy	2.293** (0.843)	2.303** (0.842)	2.312** (0.825)
Ind: Financials	0.81 (0.941)	0.894 (0.949)	1.134 (0.941)
Ind: Health Care	-0.465 (0.829)	-0.475 (0.852)	-0.327 (0.839)
Ind: Industrials	1.782* (0.875)	1.942* (0.878)	2.029* (0.859)
Ind: Information Technology	0.687 (0.89)	0.882 (0.931)	0.509 (0.922)
Ind: Materials	3.626*** (0.879)	3.882*** (0.888)	3.862*** (0.869)
Ind: Utilities	4.915*** (0.924)	5.211*** (0.945)	4.935*** (0.93)
Country Fixed Effects	All neg and N.S.	All neg and N.S.	All neg and N.S.
Year Fixed Effects	All neg and N.S.	All neg and N.S.	All neg and N.S.
Reduction Trgt x Functional Scope			1.865 (3.638)
Reduction Trgt x VC Phys. Scope			-1.762 (7.602)
Reduction Trgt x ES Phys. Scope			-22.478** (8.428)
Adj. R^2 (Overall)	0.606	0.608	0.626
F-Stat (degrees of freedom)	10.238*** (21 , 105)	9.149 *** (24 , 102)	8.796*** (27 , 99)
Observations	127	127	127
Number of Firms	62	62	62

***, **, *, ~ indicate significance at the .001, .01, .05 and .1 levels. (Standard Errors in parentheses). All coefficients relative to effect on ln(CO2) a US firm in the Consumer Discretionary industry with sales < 5 billion USD, reporting for 2005

In panel C of Table 18, after interacting the three measures of IS with the reduction target variable, we observe the following results: First, the reduction target is significant (p = .022) and in the positive direction. Second, incentives are marginally significant (p= .069) and in the positive direction. Third, the interaction of reduction targets with enterprise support is significant (p= .009), with a large coefficient in the negative direction. As before, the sign on the incentive and reduction plan coefficients indicate that these practices are positively associated with CO_2 emissions rather than negatively associated with them, which is in the opposite direction of what we hypothesized.

However, because there is a significant interaction between reduction targets and ES Physical Scope, it may be misleading to interpret the main effect of reduction targets depending on whether or not the interaction is disordinal (that is, whether the effect of reduction targets on CO_2 emissions changes for different levels of ES physical scope). To investigate this possibility, as well as to aid in interpretation of the effect, we calculate and plot the predicted values of ln(Scope12) at three levels of ES physical scope and present the results in Figure 6. This investigation confirms that there is a disordinal (crossed) interaction between ES Physical Scope and Reduction target, which makes it misleading to interpret the main effects of either. However, because the interaction term is significant at the 1% level, we can reject the null hypothesis that there is no significant interaction between ES Physical Scope and Reduction target, thus supporting Hypothesis 4a. VC physical scope, greater functional scope and both their interactions with reduction targets are not significant (p-values of 0.745, 0.635, 0.817 and 0.609 respectively), demonstrating no support for H3a and H5a. As might be anticipated, the results from all three panels indicate that industry and size controls are consistently influential factors associated with CO_2 emissions.

To help build our understanding at this early stage of investigating IS impacts on organizational GHG emissions, we conduct a supplemental analysis to ascertain whether the primary analysis results observed above also hold individually for Scope 1 (direct) and Scope 2 (indirect, purchased energy) GHG emissions. The results are presented in Table 19. The patterns of signs and significance for panels A and B of Table 19 are similar to the patterns observed in the comparable results in panel C of Table 17. One of the primary differences is that it appears the significance of reduction targets on increasing CO2 emissions is being driven by Scope 2 emissions. It is also interesting to note that, unlike the total CO2 emissions analysis presented in Table 17, the Scope 2 analysis of aggregate IS asset measures has marginal significance for the interaction of reduction targets with functional scope ($p = .08$) and physical scope ($p = .089$). In conjunction with a significantly positive coefficient on reduction targets, this lends support for H2c that IS assets of greater physical scope will interact with a firm's emissions reduction targets to moderate their impact on its Scope 2 GHG reductions. It also demonstrates lack of support for H3c, because both the coefficient on reduction targets and the interaction of reduction targets and functional scope are positive, in the opposite direction of the hypothesis. Panels A and B also indicate that the drivers of the significant increase in CO2 emissions from incentives appear to be Scope 1 emissions, and demonstrate no support for H1b, H1c, H2b and H3b.

The patterns of signs and significance for panels C and D of Table 19 are similar to the patterns observed in the comparable results in panel C of Table 18. As with the aggregated IS asset analysis, the drivers of the significant increase in CO2 emissions from incentives appear to be Scope 1 emissions.

Table 19. OLS Regression Estimates of IS Asset and Capability Effects on Scope 1 and Scope 2 CO2 Emissions

Variable	A. Aggregate IS Assets & Scope 1 Emissions (direct)	B. Aggregate IS Assets & Scope 2 Emissions (purchased energy)	C. Disaggregate IS Assets & Scope 1 Emissions (direct)	D. Disaggregate IS Assets & Scope 2 Emissions (purchased energy)
Intercept	9.09*** (1.492)	10.679*** (1.274)	8.748*** (1.467)	10.58*** (1.255)
Environmental Orientation	0.008 (0.008)	0.002 (0.007)	0.013 (0.009)	0.005 (0.007)
Reduction target	0.79 (0.491)	1.005* (0.449)	0.966~ (0.547)	1.259** (0.46)
Incentives	0.971** (0.355)	0.498 (0.347)	0.906* (0.408)	0.434 (0.346)
Greater ERP Functionality	-1.468 (3.343)	-3.778 (2.909)	-0.368 (3.654)	-2.263 (3.125)
Physical Scope (VC + ES)	4.155 (5.799)	6.467 (5.108)		
VC Physical Scope			1.697 (7.219)	3.006 (6.174)
ES Physical Scope			4.197 (7.395)	8.376 (6.268)
Controls				
Size (Sales $5B-$10B)	1.943*** (0.475)	2.262*** (0.439)	2.363*** (0.529)	2.328*** (0.439)
Size (Sales $10B-$25B)	2.939*** (0.673)	3.407*** (0.599)	3.548*** (0.737)	3.46*** (0.594)
Size (Sales > $25B)	1.19* (0.497)	1.452** (0.461)	1.623** (0.537)	1.538** (0.456)
COGS	-0.705~ (0.417)	-0.315 (0.385)	-0.861~ (0.497)	-0.345 (0.381)
Consumer Staples	1.473 (0.942)	1.13 (0.81)	1.722~ (0.941)	1.183 (0.798)
Energy	3.938*** (0.919)	0.645 (0.798)	3.603*** (0.932)	0.625 (0.786)
Financials	0.267 (1.074)	1.268 (0.908)	0.425 (1.052)	1.39 (0.895)
Health Care	-0.744 (0.958)	-0.188 (0.811)	-0.646 (0.937)	-0.185 (0.799)
Industrials	2.617** (0.951)	0.98 (0.829)	2.425* (0.958)	1.049 (0.818)
Information Technology	-0.873 (1.013)	0.681 (0.863)	-0.485 (1.031)	0.801 (0.878)
Materials	4.226*** (0.951)	2.737** (0.835)	4.759*** (0.973)	2.86** (0.828)
Utilities	6.584*** (0.978)	1.392 (0.889)	6.406*** (1.063)	1.368 (0.885)
Country Fixed Effects	All N.S.	All N.S.	All N.S.	All N.S.
Year Fixed Effects	All N.S.	All N.S.	All N.S.	All N.S.
Reduc Trgt x Fcnl Scope	4.787 (3.6)	5.535~ (3.134)	1.555 (4.049)	2.397 (3.464)
Reduc. Target x Phys. Scope	-9.572 (6.816)	-10.419~ (6.069)		
Reduc Trgt x VC Phys. Scope			-1.279 (8.472)	-2.611 (7.237)
Reduc Trgt x ES Phys. Scope			-24.935* (9.434)	-21.517** (8.024)
Adj. R^2 (Overall)			0.691	0.46
F-Stat (degrees of freedom)	13.404*** (25 , 120)	4.997*** (25 , 101)	11.141*** (27 , 98)	4.976*** (27 , 99)
Observations	126	127	126[22]	127
Number of Firms	62	62	62	62
***, **, *, ~ indicate significance at the .001, .01, .05 and .1 levels. (Standard Errors in parentheses). All coefficients relative to effect on ln(CO2) a US firm in the Consumer Discretionary industry with sales < 5 billion USD, reporting for 2005				

[22] More firms report Scope 1 than Scope 2. Because of this, the Scope 1 analysis could be re-run on 146 observations across 72 firms. The patterns of signs and significance were identical to those shown in panel C.

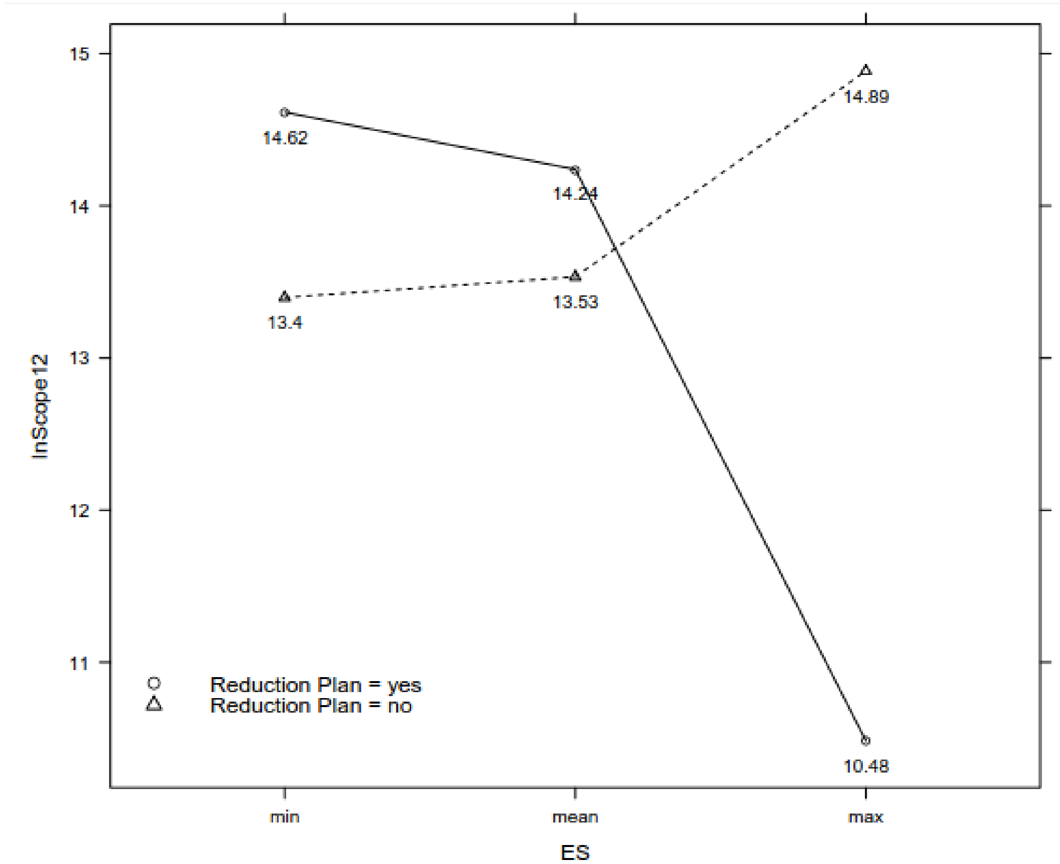
The results also suggest that the significance of reduction targets on increasing CO_2 emissions are again driven by Scope 2 emissions, but it is misleading to attempt to interpret that effect in the presence of a significant interaction. What these can tell us, however, is that the resulting patterns of support for hypotheses related to Scope 1 and Scope 2 emissions follow those of the combined GHG emissions.

In summary, H1a, b and c are not supported, as no analysis indicated that reduction targets were associated with a significant reduction in CO_2 emissions. Also not supported are H2a and H2b, though there is some weak support for H2c. H3a, H3b and H3c regarding IS capabilities represented by functional scope are not supported. However, H4a, H4b and H4c regarding the interaction of enterprise support assets and reduction targets were supported across all analyses. Value chain asset interactions with reduction targets hypothesized about in H5a, H5b and H5c are not supported. While we do not have evidence to suggest why in this study, it is possible that the time frame for our data (2005-2009) were early enough that CO_2 emissions management had not yet become deeply embodied in the average company that uses value chain modules for their core production processes. It could be that acquiring data from a later time period would begin to show an interaction for IS-supported value chain activities as companies incorporate these goals into their normal operations. Support for the hypotheses is summarized in Table 20.

Table 20. Summary of Hypotheses Support

#	Hypothesis	Supported
H1a:	GHG emissions reduction targets in organizations will be associated with reduced overall GHG emissions (improved environmental performance).	No
H1b:	GHG emissions reduction targets in organizations will be associated with reduced Scope 1 GHG emissions (improved environmental performance).	No
H1c:	GHG emissions reduction targets in organizations will be associated with reduced Scope 2 GHG emissions (improved environmental performance).	No
H2a:	IS assets of greater physical scope will interact with a firm's emissions reduction targets to moderate their impact on its overall GHG reductions.	No
H2b:	IS assets of greater physical scope will interact with a firm's emissions reduction targets to moderate their impact on its Scope 1 GHG reductions.	No
H2c:	IS assets of greater physical scope will interact with a firm's emissions reduction targets to moderate their impact on its Scope 2 GHG reductions.	Yes
H3a:	IS capability indicated by greater functional scope will interact with a firm's emission reduction targets to moderate their impact of on its overall GHG reductions.	No
H3b:	IS capability indicated by greater functional scope will interact with a firm's emission reduction targets to moderate their impact of on its Scope 1 GHG reductions.	No
H3c:	IS capability indicated by greater functional scope will interact with a firm's emission reduction targets to moderate their impact of on its Scope 2 GHG reductions.	No
H4a:	Enterprise Support assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its overall GHG reductions.	Yes
H4b:	Enterprise Support assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its Scope 1 GHG reductions.	Yes
H4c:	Enterprise Support assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its Scope 2 GHG reductions.	Yes
H5a:	Value Chain assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its overall GHG reductions.	No
H5b:	Value Chain assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its Scope 1 GHG reductions.	No
H5c:	Value Chain assets of greater physical scope will interact with a firm's emission reduction targets to moderate their impact on its Scope 2 GHG reductions.	No

Next we further interpret the interaction effects presented in Figure 6 to explore how the impact of having a reduction target for CO2 emissions changes for different ratios of ES packages with greater physical scope. The following narrative interprets the numeric results of the analysis presented in panel C of Table 18 utilizing disaggregated IS assets and a combined CO2 measure (both Scope 1 and Scope 2).



Differences between the points on the no reduction target (plan) line are not significant (p = .368).
Differences between the points on the yes reduction target (plan) line are significant (p = .0168).
Differences between the two lines for a given level of ES are significant at the min and max ES values (p=.0218 and .0196 respectively), but not the mean (p=.8969).

Figure 6. Interaction Effect of Greater ES Physical Scope on the Reduction Target / CO2 emissions relationship (two-way interaction with continuous moderator)

Holding all other model covariates at their averages, companies with no ES packages with greater physical scope are associated with higher emissions (by 1,566,532[23] additional metric tons of CO2) when they have a reduction target than when they do not

[23] e^(14.61508)- e^(13.39705) = 2,224,588.94 – 658,057.23 = 1,566,531.71. All CO2 emissions amounts in this section are calculated similarly.

have a reduction target. Simple slope analysis indicates that this is significant at the 5% level (p=.0218). For reference, this amount of CO2 is 118% of the raw (before log transformation) median value for Scope 1 and 2 emissions in our sample, which is 1,327,272 metric tons of CO2. However, this relationship eventually reverses as the ratio of ES packages with greater physical scope increases. Companies with the mean number of ES packages with greater physical scope per total sites (.023) are still associated with higher emissions (+773,506 metric tons of CO2) when they have a reduction target in place, though the difference between having a plan and not having a plan is not significant at this level of ES (p=.8969).

The maximum predicted reduction in CO2 based on the ratios of ES packages with greater physical scope observed in our sample (.25) is calculated to be -2,879,889 metric tons of CO2 lower (significant, p=.0196) for a company with a reduction target than without. The crossover point where the ratio of ES packages with greater physical scope large enough to achieve lower CO2 emissions with a reduction target in place than without it occurs at .054188, less than one standard deviation above the mean value. Within our sample of 127 firm-year observations, 23 of the observations (18.1%) are above this threshold. These results suggest that emissions reductions are only associated with the firms with the largest diffusion of ES packages with greater physical scope. These may thus represent a "leader" class of firms with IS asset bases for informating that are of sufficient scope to effectively leverage when implementing CO2 emissions reductions practices.

If an average firm with a plan to reduce emissions and a ratio of ES physical scope packages set at the sample mean were to instead increase their ES physical scope ratio by one standard deviation (by .038 to .06076), *ceteris paribus* that firm would realize a decrease in GHG emissions of 712,164 metric tons of CO2. This represents a 46.63% reduction in absolute emissions. Simple slope analysis[24] further indicates a significant (p=.0168) and negative (slope = -16.5) relationship between the ratio of ES packages with greater physical scope and logged CO2 emissions for firms with reduction targets. Conversely, firms without reduction targets do not have a significant relationship between the ES measure and logged CO2 emissions, though the sign is positive (p=.368).

Robustness Checks

Recall that the correlation between the VC physical scope measure (GrtPhysVCF) and the greater functional scope measure (GrtFcnProp1) is relatively high at .707 and significant at the 1% level[25]. This suggests a potential for multicollinearity in our final model, which we test for by calculating the variance inflation factors (VIF) for each of the covariates of interest in the model. A heuristic is that any VIF above 2 indicates a potential problem with multicollinearity. As shown in panel A of Table 21. VIFs are unacceptably high for many variables, and highest for the VC physical scope and greater functional scope measures. This could potentially be an artifact of how the greater functional scope measure was constructed and aggregated to the corporate level (because greater functional scope is defined as having a full ERP installed *or* having 2 or more VC modules installed). To the extent that the functional scope variable captures the same

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[24] Following (Dawson, 2013), Slope is calculated as $\beta_1 + \beta_3 x Z$ where β_1 is the coefficient on PhysES, β_3 is the coefficient on the interaction term of PhysES and ReductionPlan and Z is the value of ReductionPlan at a particularly point, in this case 1 or 0). Significance is calculated by constructing a t-statistic as the ratio of the slope to its standard error.

[25] The correlation between GrtPhysVCF and GrtPhysBoth is higher at .859, but GrtPhysVCF is a component of GrtPhysBoth and these are not entered into a model together so these types of correlations are ignored in this check.

information as the VC physical scope variable, it may not be an appropriately unique measure for IS capability.

As a robustness check, we temporarily assume that the theorized IS capability is jointly captured (along with the IS asset) in the VC and ES greater physical scope measures. We then re-conduct the primary analyses and present the results in panel B of Table 21. Variance inflation factors are presented in panel C and are much lower (though many are still not below the commonly used threshold of 2). Thus, while we cannot say that multicollinearity is no longer an issue, we can say that it is greatly reduced. Examining these results, the patterns of signs and significance for all variables is consistent with the analysis presented in panel C of Table 18, with the exception of VC physical scope, which changes to a negative sign but remains not significantly different from zero).

A second major concern with the primary analysis of this paper is that there may be unobserved heterogeneity between individual firms in how they account for and report GHG emissions. While the use of accounting and reporting standards developed and promulgated specifically for GHG emissions (e.g. the GHG protocol from the World Resources Institute (WRI)) can alleviate this concern somewhat, an alternate approach available to researchers to account for this (and any other firm-specific heterogeneity) is to examine year-to-year changes in GHG emissions instead of absolute emissions levels. Unfortunately, in our data set of 127 firm-year observations across 62 firms, only 39 firm-year observations across 31 firms had all requisite data available. The degrees of freedom resulting from estimating a model with 27 variables on a sample of 39 observations severely limit the statistical power of inference tests and result in coefficient estimates driven largely by sample selection. We thus are unable to rule out unobserved heterogeneity between firms' reporting practices as a concern. However, any reporting practices associated with industry or national standards is controlled for.

Table 21. Variance Inflation Factors and Regression Results of Robustness Check

Variable	A. Interaction Model VIFs (Panel C. Table 18)	B. Interaction Model without Greater ERP Functionality Measure	C. Interaction Model VIFs (Panel B.)
Intercept		10.736*** (1.297)	
Environmental Orientation	1.64	0.009 (0.007)	1.51
Reduction Target	2.32	1.159* (0.474)	2.27
Incentives	1.69	0.632~ (0.352)	1.62
Greater ERP Functionality	13.97		
Value Chain Physical Scope	10.11	-0.193 (4.328)	4.58
Enterprise Support Physical Scope	3.29	5.06 (6.275)	3.04
Controls			
Size (Sales $5B-$10B)	2.52	2.172*** (0.455)	2.49
Size (Sales $10B-$25B)	3.08	3.357*** (0.606)	2.96
Size (Sales > $25B)	2.08	1.444** (0.466)	2.01
COGS	2.48	-0.454 (0.396)	2.46
Ind: Consumer Staples	4.82	1.368 (0.829)	4.79
Ind: Energy	4.48	2.303** (0.818)	4.47
Ind: Financials	3.32	1.137 (0.931)	3.3
Ind: Health Care	3.79	-0.383 (0.816)	3.64
Ind: Industrials	2.77	2.012* (0.851)	2.76
Ind: Information Technology	3.19	0.529 (0.889)	3.01
Ind: Materials	4.75	3.882*** (0.86)	4.73
Ind: Utilities	5.68	4.941*** (0.917)	5.62
Country Fixed Effects		All neg and N.S.	
Year Fixed Effects		All neg and N.S.	
Reduction Trgt x Functional Scope	14.03		
Reduction Trgt x VC Phys. Scope	10.65	1.179 (4.93)	4.56
Reduction Trgt x ES Phys. Scope	3.2	-21.795** (8.201)	3.08
Adj. R^2 (Overall)		0.608	
F-Stat (degrees of freedom)		9.654 *** (25 , 101)	
Observations		127	
Number of Firms		62	
***, **, *, ~ indicate significance at the .001, .01, .05 and .1 levels. (Standard Errors in parentheses). All coefficients relative to effect on ln(CO2) a US firm in the Consumer Discretionary industry with sales < 5 billion USD, reporting for 2005			

Table 22. Number of Year Observations per Firm

Years of Data Available (mean 2.08 yrs.)	**Number of Firms**	**Firm-year Observations (n)**
4	5	20
3	14	42
2	22	44
1	21	21
Total	62	127

A final concern is the potential for endogeneity in our model. The variable of most concern for this would be the Environmental Pillar score calculated by the third party rater ASSET4. The reason is that 25% of the score's weight is determined by emissions reductions (measured in revenue adjusted metric tons). By using the score from the same year as the emissions we are measuring, we introduce a lag structure into our measurement of environmental orientation, since the score for the current year is calculated from historical data. There is a possibility, however, that ASSET4's practice of updating their ratings on a rolling basis may have caused some partial endogeneity. Under the conditions that (1) ASSET4's score update was performed near the end of the reporting year and (2) the company had publicly reported its CO2 emissions for part of the year already, then the EnvScore may be based in part on the same emissions data that serves as our dependent variable. An example of when this could happen is if a company reports their emissions publicly on a fiscal year cycle, but reports to the CDP on a calendar year basis. We have reached out to our data provider to clarify the likelihood of this possibility, but at this time, we cannot rule it out completely. To the extent that this does not happen, however, it is unlikely that a score based partially on prior years' emissions would be affected by the current year's emissions.

Limitations and Further Study

Although this is one of the first studies of its kind, this early-stage work has several limitations, many of which may be addressed by future research. First, correlation is not causation and in our pooled analysis, despite controlling for individual year, country, industry, and size fixed effects, we may not have adequately controlled for potential variance in the error terms. The lagged nature of the IS variables is based on theory and prior results that show it takes time for the influence of IS to be realized. However, the empirical literature on management practices leading to reduced CO_2 emissions is not as well developed and there may be similar lags or other, yet-undiscovered management practices that explain emissions reductions better than reduction targets, incentives, and third-party environmental ratings. In fact, our data did not allow us to fully incorporate the one relevant management practice that had been found to have an effect on emissions, namely decomposing incentives into either monetary and non-monetary categories and classifying whether they are targeted at managers in charge of environmental performance or other employees (Eccles et al., 2013). Further decomposing these incentives may aid us in exploring the IS impacts in the future.

It is also likely that there is some amount of simultaneity between reduction targets and CO_2 emissions. One explanation for having a reduction target is that a company's emissions are large enough to warrant regulation. We have attempted to control for this in a number of ways, most notably by controlling for company size, inputs (COGS) and, highly relevant to many targeted regulations, industry and country. However, as more data become available to us, it may be possible to control for industry at a level lower than the sector, better explaining differences between firms. Within-firm changes in emissions year to year would also help control for this, though more data will need to be available than that currently described in the second robustness check.

The IS data represent both a strength and a limitation of this study. In addition to being highly detailed (modules installed at the site level), the sampling methodology used by the IT survey firm to update the data has the likely effect of reducing the correlation of the error terms from year to year to an amount lower than might otherwise be expected. This same feature, however, of updating company results with different sites each year, also results in a noisier measure of ERP package adoption, possibly weakening and/or obscuring the significance of the classes of ERP packages. Additionally, for companies with relatively few sites, but whose packages all span multiple sites, the calculated IS ratio will be higher than companies with more sites, even if they have the same number of ES or VC packages and just as strong (or even stronger) IS capability. Thus, by adopting a "Packages per site" measure for the physical scope IS variables, we may have understated the IS assets in place for organizations with a greater number of sites. Additionally, the core usefulness of enterprise modules is in organizational integration, with integration maximized when as many functions as possible are consolidated within the same ERP of inter-related packages. Thus, if achieving additional functionality would require implementing a module from a competing or non-compatible ERP system than the others installed, the benefits of integration could potentially decrease with an increase in the number of modules. A strong potential for future research is to refine the measure of IS used to account for these limitations and avoid the multicollinearity of the present greater functional scope measure.

Conclusion

As companies respond to pressures to measure and manage their GHG emissions, knowledge of which practices, assets, and capabilities are relevant in influencing those emissions are vital. This work presents some of the first empirical evidence of how different classes of installed IS assets can affect an organization's GHG emissions. While subject to a number of important limitations that are planned to be addressed in future versions of this research, the core finding of this paper is that certain IS assets, namely ERP modules for Enterprise Support (including Accounting, Financial, and Human Resources packages) interact with firms' reduction targets to moderate the impact those targets have on GHG emissions. In our sample, if an average firm with a plan to reduce emissions and a ratio of ES physical scope packages set at the sample mean were to instead increase their ES physical scope ratio by one standard deviation (by .038 to .06076), *ceteris paribus* that firm would realize a decrease in GHG emissions of 712,164 metric tons of CO2. This represents a 46.63% reduction in absolute emissions). Thus, this study represents one of the first attempts at empirically quantifying a relationship between enterprise IS and GHG emissions and provides a base for further inquiry.

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Chapter 5 Final Considerations

In this dissertation, I examine the impacts of Information Systems (IS) on firm performance when either the IS or the measure of performance itself is directly related to greenhouse gases emitted into the natural environment. While IS research has examined many dimensions of firm performance in the past, this work is among the first to offer empirical econometric evidence of enterprise IS impacts on GHG emissions. It is also among the first to investigate the financial impacts (expressed in terms of market valuation) of carbon management systems (CMS). Chapter 2 contributes to disciplines outside IS through its methodological investigation of short-window event studies in international settings. The calculation of bias can result from using a single-factor model in an international setting and the error correction achieved by using a multiple-factor model is of potential interest to scholars in accounting, management, finance and beyond. The examination of an international methodology arose from the international nature of CMS adoption. Driving this international adoption are worldwide coordinated efforts to address the shared problem of global warming caused by anthropogenic greenhouse gas emissions.

I have sought, in this dissertation, to make a beginning at building our understanding of what makes firms successful (and unsuccessful) when applying IS to environmental problems. Discovering that financial markets punish companies for implementing CMS after regulations are in place indicates that waiting too long before taking action may be a misstep that managers want to avoid. Conversely, learning that superior experience with enterprise support modules of ERP systems (such as accounting and finance) are associated with enabling management reduction goals to result in GHG emissions reductions highlights the areas and types of talent that managers may want to focus on when they strive to achieve environmental goals.

I have attempted to draw a boundary around my investigations limiting them to large profit-making organizations. This by no means indicates that I do not advocate for other levels of environmental responsibility (e.g. individual), action (e.g. state or trans-national), or even structures of achieving production (e.g. cooperatives and b-corps). Rather, this focus is because business organizations are a major source of greenhouse gas emissions that have the ability to do something about those emissions when properly equipped with tools and motivation.

IS represent an important (and in some organizations indispensable) enabling technology for managing greenhouse gas emissions, as evidenced in this dissertation's three essays. The business value of IS literature leads us to expect that some firms may be extraordinarily successful adapting to and utilizing this new type of enterprise information system. That same literature also leads us to expect that other firms will struggle, and perhaps even fail in realizing the objectives of the system. The nature of firm characteristics, both in management practices, IS assets, and IS capabilities represent important contingencies for the realization of value. Chapter 4 represents a first attempt to start understanding the direction and conditions under which these characteristics interact to influence firm greenhouse gas emissions. Future research based on this work will further investigate the nature of these interactions. This dissertation thus represents an early step in seeking a better understanding of how IS assets and capability can empower organization managers to achieve their environmental goals and help make the world a better place for us all.