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Abstract

Global organizations employ information systems (IS) to manage energy and carbon emission information. However, we know little about the factors associated with their adoption. Using primary data collected from a single organization, we first develop a simple conceptual framework for this class of information system comprised of information technology (hardware and software), business processes, and work practices. Then, we conduct an exploratory empirical analysis into the extent to which global climate agreements and managerial practices are associated with their adoption. Our analysis suggests that managerial incentives and carbon reduction targets are strongly associated with the adoption of systems for managing energy and carbon emission information. We discuss the implications of our findings and suggest future research avenues.

1. Introduction

Organizational leaders are increasingly emphasizing environmental sustainability as a strategic imperative [55], driven by energy costs, consumer and shareholder pressure, risk exposure, and workforce satisfaction [30]. As a result, many firms are setting quantitative performance targets to reduce energy and carbon emissions [51]. However, it is difficult to manage what is not measured, and new information systems (IS) are required for new environmental strategies. As one executive put it: “The board of our company put sustainability high on the corporate agenda this year, but realized that the key inhibitor for defining and executing our corporate sustainability strategy is the lack of transparency into our carbon footprint.” [26, p. 4].

What do we know about how information systems are used in large organizations to manage energy and carbon emissions? Researchers have examined various issues related to diverse uses of IS for environmental management in industry [53, 43], including geographic information systems, traffic and logistics, hazardous waste, material flow, environmental reporting, and recycling [40]. In addition, case studies provide insight into situational specifics, such as energy informatics and telematics at UPS [56], interorganizational IS used to support lifecycle management in the supply chain at ASG [48], and IS for knowledge sharing between environmental and business units at Rhone-Poulenc [21]. These and other emerging studies provide a solid foundation on which to develop a strong stream of research related to IS and environmental sustainability.

[5, 13, 33, 57, 14, 23, 45, 42]. At the same time, studies focused on IS for managing energy and carbon emission information in large corporations are not abundant, and we could find no studies using large data sets enabling quantitative empirical analysis of adoption antecedents.

Our research goal is to make a modest contribution to the literature by addressing this important knowledge gap. We conduct a quantitative empirical analysis examining adoption antecedents of IS for managing energy and carbon emission information in large organizations. We focus on this area of IS for environmental sustainability as it is both economically significant (estimated to be a $1.3 billion market in 2011 [38]) and environmentally significant (global corporations are responsible for a significant amount of carbon emissions).

We examine the following research question: How are IS for managing energy and carbon emission information used in organizations, and what factors are associated with their adoption? The first aspect contributes to what we know by synthesizing and bounding phenomena of interest, while enhancing managerial decision making by developing a framework specifying inputs, outputs, information technologies, business processes, and work practices. The second aspect of our research question contributes to what we know by exploring new adoption issues for this new context, specifically, the role of environmental regulations and managerial incentives.
This builds on and extends a long line of IS adoption research using the technology-organization-environment framework [54].

Overall, our empirical results suggest that adoption is positively associated with environmental targets and managerial incentives. In contrast, we find no statistically significant association between adoption and global carbon reduction agreements (legally binding or non-legally binding). We explore various interpretations in the discussion section, which leads to fruitful suggestions for future research.

In the next section we develop a conceptual framework for IS for managing energy and carbon emission information using primary case study data. Then, we discuss prior research and develop propositions. We next describe empirical modeling, data sources, and variables, and present our empirical analysis and results. We conclude by discussing and summarizing our findings and their limitations, and by suggesting future research studies.

2. IS for managing energy and carbon emission information

We could not identify any prior quantitative empirical studies that examine IS for managing energy and carbon emissions, projected to be a $5.7 billion market by 2017 [38]. We did find a few related studies. One article reviews the current state of “carbon management systems” from a technological perspective [27]. A recent working paper comprises a case study of a single organization [34]. A third study explicates tools for assessing sustainability, though IS are not the focus [37].

Given the importance of precise terminology that defines phenomena of interest [37] and the rapidly changing nature of this class of information system, we decided to collect primary data from a single organization to generate insights that form the basis for our conceptual framework. We collected primary data in 2010 via interviews and publicly available information. We emphasize that these data are not intended to comprise a formal academic case study. Rather, our grounded approach to collecting first-hand observations was meant to capture a holistic, system perspective of phenomena of interest, thereby limiting potential research bias.

2.1. Insights from MU

MU is a large public university with more than 30,000 students; 20,000 staff; and 5,000 faculty members located in the U.S. Midwest. In the past decade, MU has developed numerous strategies and initiatives focusing on environmental sustainability. For example, in the early 2000’s MU initiated a strategic commitment to publish an annual sustainability report that includes data on energy, carbon emissions, and other environmental metrics. The environmental, health, and safety (EHS) group within MU developed new information capabilities to meet these new information requirements. Similar to many organizations in the public and private sector, a spreadsheet-based approach was developed to gather, store, analyze, and report pertinent environmental information. The process occurs on an annual cycle and comprises five steps: 1) EHS emails data requests to units throughout MU requesting that an attached spreadsheet be completed with environmental data such as water usage and energy usage; 2) business unit completes spreadsheet via data entry or by cutting and pasting from other systems; 3) EHS receives completed spreadsheet and uses a macro to automatically join the data with a larger spreadsheet; 4) EHS uses a complex macro to aggregate data across all units and compute statistics such as carbon emissions based on various parameters; and 5) EHS creates user-friendly graphs and tables for use in the annual sustainability report.

In 2011, an extensive integrated assessment was conducted to determine the future of sustainability at MU in the areas of research, teaching, and campus practices. One result was that the university president set specific carbon emission reduction targets. Given the newness of the integrated assessment, it is not clear how these targets and potential new campus initiatives will drive new information demands. Possibilities include more detailed data collected at more frequent intervals (e.g., monthly), a focus on supply chain partners such as food vendors, the use of smart energy meters for campus facilities, and the implementation of incentives for energy reduction and carbon emission reduction. It may be the case that the spreadsheet approach will not be compatible with new information requirements, though this remains to be seen.

Based on data collected about MU, it is clear that IS for managing energy and carbon emission information include information technologies (desktop computer, networking, Microsoft Excel, etc.), business processes (five-step process described above), and work practices (e.g., process by which business unit employee manually enters data from one system to the spreadsheet template). Inputs to the IS include raw environmental data such as miles driven by corporate vehicles or electricity (kWh) used. Finally, outputs of the IS include different greenhouse gas scopes (scope 1: stationary and mobile combustion; scope 2: purchased energy; scope 3: supply chain, employee travel, etc.), tables and graphs for sustainability reports, decision-making tools, and so forth. These three
components of the IS (information technologies, business processes, and work practices) are consistent with a technological review of current systems, which identifies features of tracking, reporting, auditing, compliance, reduction, and emissions trading (processes and practices) as well as technological architecture (on-demand, on-premise, service oriented architecture) [27]. Finally, we note that this is an emerging domain that is rapidly evolving. Thus, our focus on processes, practices, and information technologies is an appropriately generic level to provide an enduring and valuable perspective.

2.2. Conceptual framework

Based on the above, we define an IS for managing energy and carbon emission information as comprising information technology (hardware and software), business processes, work practices, and data procedures for managing and mitigating energy and carbon emissions in organizations, including process and measurement accuracy. To emphasize, the distinguishing features of these IS are their focus on environmental resource information; their salient role within the energy information value chain involving utilities, regulators, etc.; and the requirement that they generate information that follows emerging, evolving, and non-harmonized environmental data standards (for example, the Global Reporting Initiative).

Our focus on the concept of a system (rather than a narrow focus on information technology) is consistent with recent calls in the IS literature to focus on the system view rather than the tool view to “enhance our ability to explain and predict phenomena” [1, p. 456]. We thus present a simple framework including 1) raw environmental data inputs; 2) information processing; and 3) information, knowledge, and other outputs (Figure 1). The framework is intended to be both descriptive of what is as well as generative in terms of motivating new research directions, and is consistent with emerging research on IS and environmental sustainability [34].

On the left-hand side of Figure 1 are raw environmental data inputs, such as energy use and stationary combustion metrics (e.g., a firm-owned cogeneration facility that generates electricity from natural gas and uses the exhaust for heating buildings). These data types may be input manually or automatically, depending on various factors such as the nature of the original data. Business processes and work practices are employed to capture these metrics in some kind of information technology, which appears in the center of the framework. For example, an enterprise software system may allow business users from throughout the firm to log in and enter raw environmental data. It may also enable automatic integration of digital data, such as electricity billing data contained in other firm information systems. Outputs comprise decision-making support, graphical displays of standardized greenhouse gas (GHG) scopes, dashboards, etc. An example of the latter is the interactive web page associated with the annual sustainability report of SAP, which enables the user to choose time scales and view various measures of carbon emissions, as well as several drilldowns.

Having addressed the first dimension of our research question (how are IS for managing energy and carbon emission information used in organizations), we now turn to our second research question (what factors are associated with their adoption?).

3. Propositions

Given the lack of prior quantitative empirical analysis of adoption antecedents in this research stream, we use prior research, theory, and anecdotal evidence to build propositions related to factors in the external competitive environment and related to internal managerial structures.

3.1 External factors: global climate agreements

The IS adoption literature employs a range of variables to explain the organizational adoption of information systems [6, 22, 39, 50, 60]. The technology-organization-environment (TOE) framework [54] is a widely employed theory perspective that has exhibited reasonable explanatory power in various contexts. For example, 26% of the variation in e-business adoption by European firms is explained by technology, organization, and
environment variables [60]. Regarding environmental factors, policy instruments, mimetic pressure, competitive pressure, trading partner readiness, pressure groups, and external stakeholders have been included as explanators of adoption and intent to adopt. Notably, external pressure was found to be a significant adoption antecedent for electronic data interchange (EDI) [6] and for e-business [60]. Regarding organizational factors, size is sometimes included as an explanatory factor and found to be significant [39, 50], in addition to readiness, absorptive capacity, motivations, and employees. Finally, regarding technology, various proxies have been found to be significant, including IS capabilities and relative advantage [22].

While the TOE framework includes factors in the environment as described above, gaps in knowledge remain. The competitive environment may shape the beliefs and subsequent actions of business managers in the realm of environmental sustainability. For example, global climate agreements such as the Kyoto Protocol may shape managerial beliefs and actions in companies based in signatory countries. This line of reasoning is consistent with prior research, which finds that governmental regulations can spur changes in organizational practices [7, 41]. Anecdotes also support this reasoning, in particular, the idea that the country in which the firm is domiciled makes a difference, in this case Japan: “OMRON considers that promotion of anti-climate change measures is an important social responsibility … [our] efforts are being concentrated on promoting energy conservation to ensure the achievement of Japan's Kyoto Protocol target (a 6% reduction in greenhouse gas emissions compared to fiscal 1990).”

Institutional theory addresses complexities involving stability and change in social life, including organizations [46]. Institutions comprise cultural, normative, and regulative elements that shape and are shaped by actors such as organizations. In particular, three types of pressure bear on firms that may result in their adopting similar structures: coercive pressures (rules, laws, sanctions), normative pressures (certification, accreditation, etc.), and mimetic pressures (prevalence, isomorphism) [10].

In the IS literature, institutional theory has been used to examine and explain a range of organizational phenomena, including IS innovation processes [25], interorganizational system adoption [52], and the organizational consequences of information technology [44]. Researchers have also employed institutional theory to inform causal mechanisms related to specific types of information systems. For example, a conceptual analysis of electronic medical records (EMR) focuses on external influences on adopting organizations, analyzing the role of mimetic, coercive, and normative factors on the intention to adopt EMR [49]. Another example is an empirical analysis of the antecedents to adopting supply chain IT, in which institutional arguments are employed to motivate a research model explaining diffusion and assimilation [59]. Results indicate that institutional factors are indeed significant.

We focus on a single dimension of institutional theory pertinent to the environmental context, coercive pressure, which may arise from legal mandates or influence from other organizations they are dependent upon. In the environmental context, if a firm is domiciled in a country that is a signatory to international climate treaties, it may be more likely to adopt related IS due to coercive pressure. Moreover, the signatory status may be a reflection (or partial cause) of a broader social structure oriented to sustainability [33], which may impact the domiciled corporation. The environmental management research stream suggests that regulatory pressures may be a significant adoption antecedent [17].

Whether the agreement is legally binding or non-legally binding could have dissimilar implications for the institutional pressures faced by organizations and the consequent need for adoption of IS for environmental management purposes [28, 16]. For example, there are cases when self-regulation (non-legally binding) might reduce social welfare [29]. Finally, we acknowledge that it is difficult to make causal statements about country level variables, given that other phenomena might be salient at more granular levels. Nonetheless, consistent with prior research in environmental sustainability, the logic of institutional theory, and anecdotal evidence, we propose exploratory propositions related to two types of global climate agreements – non-legally binding and legally binding:

\[ P1: \text{A firm based in a country with a longer duration of an international non-legally binding climate agreement is more likely to adopt IS for managing energy and carbon emission information.} \]

\[ P2: \text{A firm based in a country with a longer duration of an international legally binding climate agreement is more likely to adopt IS for managing energy and carbon emission information.} \]

### 3.2 Internal factors: targets and incentives

Regarding internal management structures, the IS literature has focused on such antecedents as size, readiness, absorptive capacity, motivations, and
employees [6, 22, 39, 60]. However, given the uniqueness of the environmental context and debate over whether environmental sustainability practices generate financial versus ecological value (or both), we are interested in other variables that may motivate managers to adopt. We thus turn our attention to the environmental management literature, in particular, environmental management systems and related managerial programs.

An environmental management system (EMS) is defined as “the formal system and database which integrates procedures and processes for the training of personnel, monitoring, summarizing, and reporting of specialized environmental performance information to internal and external stakeholders of the firm” [32, p. 332]. EMS emerged decades ago as a set of organizational practices for industrial-sector firms to meet environmental regulations. EMS typically address toxic material and waste, for example, those dealing with emissions to air (sulphur dioxide, volatile organic compounds), water discharges (heavy metals), and hazardous waste. As such, EMS are distinctive in focus, features, and objectives, yet similar enough to modern IS for managing energy and carbon emission information to yield pertinent insights.

The EMS literature examines various adoption antecedents [15]. Empirical analysis of several hundred U.S. publicly traded firms suggests that liability risks and pressure from various stakeholders is a significant adoption antecedent [2]. Internal factors and incentives, including enhancement of the corporate brand, suggest that rational self-interest may explain a firm’s decision to adopt an EMS [17]. In contrast, empirical analysis of the adoption of cleaner technologies suggests that greater pressures from corporate headquarters do not have an impact on the likelihood of adoption [20]. These and other studies in the EMS adoption literature underscore the important role of management practices as adoption antecedents, despite the lack of convergence on specific antecedents that are particularly salient.

We develop two propositions concerning management structures and the adoption of IS for managing energy and carbon emission information. There is some evidence of the role of incentives and targets in promoting sustainability behaviors. For example, a case study of environmental sustainability in a technology company finds that “setting appropriate incentive systems that embody relevant target agreements are relevant to successfully adopting sustainable practices.” [47, p. 6]. One theory perspective that may shed light on incentives and targets in adoption is agency theory. Agency theory assumes that managers are self-interested, boundedly rational, and risk averse, which can lead to incongruity between their actions and those of firm owners [35]. The IS context is especially prone to agency issues due to the complexity and rapid technological progress of information systems such as those supporting environmental management, which engenders information asymmetry between IS and environmental managers who make investment decisions (agents) and chief executive officers who set organizational strategy and typically have large ownership shares (principals) [3]. Managers may not make adoption decisions that align with high-level sustainability goals set by senior executives as it may not be in their own personal interest. Moreover, information asymmetry may enable them to take these actions with impunity. How might this potential agency problem be overcome?

Positivist agency theory addresses situations in which owners and managers of firms have conflicting goals and associated mechanisms to mitigate such goal misalignment [12]. One such mechanism is outcome-based contracts. In the environmental context, this might mean that the CEO (principal) provides explicit incentives to reduce carbon emissions that are tied to performance targets. In this way, goal misalignment may be mitigated as the manager now has clear incentives to achieve the sustainability objectives of the principal. Overall, this reasoning is consistent with the proposition that “when the contract between the principal and agent is outcome based, the agent is more likely to behave in the interests of the principal.” [12, p. 60].

Empirical evidence supports the link between outcome-based contracts and managerial behavior in the context of strategic and individual choices [9], suggesting that this link may also exist in the current context. If the manager holds the prior belief that these information systems will reduce carbon emissions, we would expect that targets and incentives to reduce carbon emissions would lead to greater adoption. In the absence of such mechanisms, even though managers may hold such prior beliefs, they may not invest as carbon emission improvement is not part of their performance evaluation, thereby avoiding unnecessary risk. We also note the possibility of the reverse mechanism: environmental IS may spur adoption of incentives and targets due to its ability to enable such targets to be met. However, based on prior literature, the more likely scenario is that high-level incentives and targets are set by senior executives (strategies), while specific measures to achieve them (tactics) are left to operating managers. It is also possible that the principals have decided to set a strategy of “going green” and have initiated incentives, targets, and IS jointly. While this is indeed possible, we assume that there exists a difference between high-level strategies such as sustainability mission statements and carbon emission reduction targets set by senior executives and
lower-level decisions around how such strategies are implemented, such as business processes and the use of spreadsheets or dedicated information systems to support environmental data management. We thus formulate two additional exploratory propositions:

P3: Managerial incentives tied to carbon emission reduction are associated with a higher firm propensity to adopt IS for managing energy and carbon emission information.

P4: Carbon emission reduction targets are associated with a higher firm propensity to adopt IS for managing energy and carbon emission information.

4. Empirical methodology

4.1 Data sources

Primary data come from the Carbon Disclosure Project (CDP), which conducts an annual survey of large publicly traded global corporations. We chose CDP as it provides data on most of the variables of interest, is one of the most widely employed voluntary reporting agencies globally, and has been used in prior organizational scholarship [41]. CDP requests data on behalf of more than 550 institutional investors holding more than US$70 trillion in assets under management. The survey solicitation letter is sent from these institutional investors to Chairmen of the Board of publicly traded companies, who then forward it to high-level executives who know or can determine responses to survey items, such as environmental, health, and safety executives; chief sustainability officers; or the equivalent.

We employed data from CDP 2008, whose sample frame comprises lists of publicly traded firms such as the Global 500 totaling more than 2500 firms. Firms either 1) did not respond; 2) declined to answer; 3) provided something such as a sustainability report without survey responses; or 4) responded. For the response category, 2204 firms responded, with 1648 of those allowing use of the data for research (“public responses”). We use the Risk Metrics database for additional environmental variables, and the Bureau van Dijk’s (BVD) database for economic data of global firms. After matching firms that provided carbon emission data, IS data, and other organizational metrics, the final sample comprises 203 firms. The analysis sample is larger than the sample frame (proxied by the Global 500) in terms of revenue and assets, so we condition our results in terms of being representative of the largest global corporations. We now describe our dependent variables (IS) and independent and control variables.

4.2 Variables

The CDP 2008 survey included a question asking firms whether they have a system in place for managing carbon emissions, including for ensuring the accuracy of calculation methods, data processes, and related systems (IS) (Table 1). Whether they answered yes or no, the firm was subsequently asked to explain their response. Examining open-ended responses indicates that the binary response is indeed related to an underlying continuous measure capturing how sophisticated or advanced is the system for managing energy and carbon emission data.

We used data provided in the UN Environmental Indicators database to measure climate agreements, which lists each country and the year in which they joined either the non-legally binding United Nations Framework Convention on Climate Change (UNFCCC) or the legally binding Kyoto protocol (KYOTO). We subtracted the year in which they joined from the current year to create the measure, i.e., the longer the country has been a signatory, the longer is the time in which the domiciled firm has to respond by changing its business practices.

<table>
<thead>
<tr>
<th>Table 1. Main variables</th>
<th>Definition</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS</td>
<td>Information system for managing energy and carbon emission information</td>
<td>System in place to assess the accuracy of GHG emissions inventory calculation methods, data processes and other systems relating to GHG measurement?</td>
</tr>
<tr>
<td>UNF</td>
<td>Institutional Pressure (Not Legally Binding &amp; No Targets)</td>
<td>Number of years that country in which firm is domiciled has been a signatory to UNFCCC.</td>
</tr>
<tr>
<td>KYO</td>
<td>Institutional Pressure (Legally Binding and Targets)</td>
<td>Number of years that country in which firm is domiciled has been signatory to Kyoto Protocol.</td>
</tr>
<tr>
<td>INC</td>
<td>Managerial Incentives</td>
<td>Provide incentives for individual mgmt. of climate change issues including attainment of GHG targets?</td>
</tr>
<tr>
<td>TAR</td>
<td>Carbon Performance Target</td>
<td>Have an emissions and/or energy reduction target(s)?</td>
</tr>
</tbody>
</table>

Incentives (INC) and targets (TAR) are measured by items in the CDP database. Regarding incentives, the question asks “do you provide incentives for individual management of climate change issues including attainment of GHG targets?” while the latter asks “Do you have an emissions and/or energy reduction target(s)?” We note that these are single item constructs, which may be subject to validity concerns. However, conversations with various stakeholders suggest that firms interpret these questions as we intend, e.g., the INC question is interpreted as an...
incentive program or scheme across the organization applying to individual managers around climate change and/or carbon emission targets.

In addition to these four variables related to our propositions P1-P4 (which have not been used in prior IS adoption research to our knowledge), we included several control variables. We included a measure of environmental strategy (STRA) from RiskMetrics (now MSCI) given that this may affect adoption. The variable measures company environmental strategy against the principles of the United Nations (UN) Global Compact, a widely accepted international standard of corporate behavior, by evaluating corporate disclosure on policies. This measure is used by institutional investors, including investment managers, mutual funds, hedge funds and pension funds, such as Japan’s Pension Fund Association [36]. Second, we included a measure of environmental risk (RISK) from the CDP, for similar reasons. Third, we included the number of years for which a firm has disclosed its emissions in the CDP (DISC) weighted to account for learning curve effects, which might serve as a proxy for its environmental capabilities. Fourth, we included three additional variables: firm size (SIZE), proxied by revenue [31]; whether a firm engages in environmental trading of carbon credits (TRAD); and whether a firm is in a high-emitting industry (EMIT) [cf. 41].

5. Results

5.1 Correlations

Both INC and TAR are positively and significantly correlated with IS (.37 and .31, respectively), which is consistent with P3 and P4 (Table 2). Similarly, the correlation between IS and UNF is positive (.20), though that between IS and KYO is very small. Finally, we note that the highest correlation is between UNF and KYO (-.59), suggesting that a firm with a long history in UNFCCC might have a low history of KYOTO.

### Table 2. Correlations

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. IS</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. SIZE</td>
<td>0.09</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. EMIT</td>
<td>0.13</td>
<td>-0.02</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. TRAD</td>
<td>0.20</td>
<td>0.29</td>
<td>0.33</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. UNF</td>
<td>0.20</td>
<td>0.11</td>
<td>-0.01</td>
<td>-0.05</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 KYO</td>
<td>0.00</td>
<td>0.04</td>
<td>-0.01</td>
<td>0.18</td>
<td>-0.59</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>7. INC</td>
<td>0.37</td>
<td>-0.07</td>
<td>0.28</td>
<td>0.22</td>
<td>0.13</td>
<td>0.05</td>
<td>1</td>
</tr>
<tr>
<td>8. TAR</td>
<td>0.31</td>
<td>-0.04</td>
<td>0.18</td>
<td>0.17</td>
<td>-0.15</td>
<td>0.25</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Note: bold indicates significant at p ≤ .05.

5.2 Descriptive statistics and sample splits

Further insight into propositions can be found by splitting the sample by IS (Table 3). We observe that incentives and targets (mean value) are significantly higher in adopting firms than in non-adopting firms. These results suggest support for P3 and P4 but no support for P1 and P2 (absent controls present in regression analysis).

### Table 3. Sample splits

<table>
<thead>
<tr>
<th></th>
<th>IS = 0</th>
<th>IS = 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIZE</td>
<td>-0.212</td>
<td>0.123</td>
</tr>
<tr>
<td>EMIT</td>
<td>0.220</td>
<td>0.324</td>
</tr>
<tr>
<td>TRAD</td>
<td>0.220</td>
<td>0.57</td>
</tr>
<tr>
<td>UNF</td>
<td>14.902</td>
<td>15.425</td>
</tr>
<tr>
<td>KYO</td>
<td>3.463</td>
<td>3.486</td>
</tr>
<tr>
<td>INC</td>
<td>0.195</td>
<td>0.659</td>
</tr>
<tr>
<td>TAR</td>
<td>0.610</td>
<td>0.899</td>
</tr>
</tbody>
</table>

Note: Significance using Wilcoxon Z-stat (p ≤ .05).

5.3 Probit and logit adoption estimation

Since our dependent variable involves a binary choice, logit and probit models are appropriate. Logit and probit models account for the non-linearity of the regression while also ensuring that the predicted probabilities remain within the actual range of 0 to 1 [18]. Estimation results for the logit and probit models are reported in Table 4.

We fail to reject the null that UNF and KYO are significantly different from zero in both models, providing no support for P1 and P2. In contrast, we reject the null that INC and TAR are zero in both cases, in support of P3 and P4. All estimations are significant, with the Wald chi-square statistic significant and the pseudo-R2 reasonably substantial in both cases.

6. Discussion

In this paper we provide two main contributions to the literature. First, we gathered primary data from a single organization to generate insights into how organizations gather, store, analyze, and report energy and carbon emission information. We synthesized these insights into a simple conceptual framework bounding phenomena of interest by specifying inputs, information technologies, and outputs, as well as work practices and business process. We found that distinguishing features of these IS relative to other types of IS (in particular, enterprise resource planning systems) are their focus on environmental resource information (energy, carbon emissions, etc.), their
interdependent role in the energy information value chain (electric utilities, regulators, etc.), and their use of voluntary and rapidly evolving data standards. (e.g., the Global Reporting Initiative).

Table 4. Adoption Regression Estimation

<table>
<thead>
<tr>
<th></th>
<th>Dependent Variable: IS</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Logit</td>
<td>Probit</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td></td>
</tr>
<tr>
<td>EMIT</td>
<td>0.119</td>
<td>0.052</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.497)</td>
<td>(0.273)</td>
<td></td>
</tr>
<tr>
<td>SIZE</td>
<td>0.045</td>
<td>0.022</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.174)</td>
<td>(0.099)</td>
<td></td>
</tr>
<tr>
<td>TRAD</td>
<td>0.183</td>
<td>0.126</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.434)</td>
<td>(0.235)</td>
<td></td>
</tr>
<tr>
<td>UNF</td>
<td>0.121</td>
<td>0.059</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.175)</td>
<td>(0.100)</td>
<td></td>
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<tr>
<td>KYO</td>
<td>-0.252</td>
<td>-0.150</td>
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<tr>
<td></td>
<td>(0.181)</td>
<td>(0.093)</td>
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</table>
| INC            | 1.430 ***              | 0.785 ***| (0.548) | (0.255)
| TAR            | 1.434 ***              | 0.876 ***| (0.550) | (0.311)
| DISC           | 0.021                  | 0.014   |         |
|                | (0.049)                 | (0.024) |         |
| STRA           | 0.240                  | 0.129   |         |
|                | (0.213)                 | (0.116) |         |
| RISK           | 0.561                  | 0.307   |         |
|                | (0.518)                 | (0.299) |         |
| Log Pseudo- Likelihood | -77.54             | -77.336 |         |
| Wald Chi-square| 33.12***              | 37.97***|         |
| Pseudo R-square| 0.33               | 0.345   |         |
| AIC            | 177.08                 | 176.672 |         |
| BIC            | 213.526                | 213.117 |         |
| Classification accuracy | 81.77%             | 81.77%  |         |
| N              | 203                    | 203     |         |

Note: *** p < .01; ** p < .05; * p < .1 Robust standard errors used. AIC (Akaike information criterion) and BIC (Bayesian information criterion) are measures of model goodness of fit. Classification accuracy indicates the percentage of sample points for which the predicted dependent variable equals the actual value.

These insights suggest future avenues of research involving the energy information value chain, theory perspectives such as adaptive structuration theory [8] and the automate-informate-transform perspective [61], and further examination of situational specifics at the nexus of IS and environmental sustainability. For example, what unique barriers to adoption and successful implementation exist and how might they be overcome?

Second, results of our quantitative empirical analysis of adoption antecedents suggest that managerial incentives as well as carbon emission reduction targets are significantly associated with the likelihood of adopting more advanced systems for managing energy and carbon emission data. These results are consistent with the general sustainability habits of “top performers,” who are more likely to innovate to achieve competitive differentiation, to quantify benefits, and to rely on managers and line leaders to drive sustainability [19]. This suggests a proposition for future research: successful firms develop a set of mutually reinforcing practices that include advanced information technologies, managerial structures, and business processes and work practices. Complementarities might be used as theory perspective to examine such a proposition [4].

We did not find strong statistical significance regarding the role of global climate agreements, findings, which is not entirely consistent with prior research of environmental management systems [24, 58]. Many explanations might underlie these results, including the presence of unmeasured heterogeneity in our data set. Further research using alternative data sets would refine our results and help to identify underlying causal mechanisms. For example, conducting a primary survey into the role of where a firm is domiciled on its sustainability beliefs, culture, and actions may shed further light on the role of external factors in the competitive environment.

Beyond adoption antecedents, our exploratory study suggests other research questions related to IS for managing energy and carbon emission information. First, what is the business value of such systems? Is there a financial component and a sustainability component, and how might they interrelate? Second, given the involvement of new stakeholders (environmental managers, organizations such as Greenpeace, consumer activists, etc.), does the diffusion and assimilation of green IS differ versus that of conventional IS, and in what ways? Lastly, will the trajectory of the underlying information technologies merge with conventional enterprise resource planning systems spurred by the potential emergence of integrated financial reporting [11]? Finally, we note that our empirical analysis is subject to limitations of any study of this type, including the difficulty in showing causality and the potential for endogeneity and sample response bias, among others. Though we have endeavored to minimize these threats in our research design, we cannot guarantee their absence, which provides further impetus for future replication and extension studies.

In summary, this research stream focused on information systems for managing energy and carbon emission information has great potential to accelerate the translation of corporate strategies into concrete management practices that reduce harmful, human-caused carbon emissions, benefiting organizations as well as society.
7. References

[34] N. P. Melville and R. Whisnant, "Environmental Sustainability 2.0: Empirical Analysis of Environmental ERP


