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An Empirical Examination of the Use of IS-enabled Sustainability Initiatives Across the Integrated Sustainability Framework

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Abstract

Background: *Using the Resource Based View (RBV) and the Integrated Sustainability Framework (ISF) as theoretical foundation, this study proposes and empirically examines hypotheses on how different types of IS-enabled sustainability initiatives are used to enable environmental and social sustainability in the four quadrants of the ISF.*

Method: *The study uses a mixed-method approach, combining multiple-case study and non-parametric statistical analysis (Friedman test). IS-enabled sustainability initiatives were collected from Global Reporting Initiative (GRI) reports of six leading global sustainability companies across three industries with different levels of IS/IT use intensity during 2009-2015 period.*

Results: *The study finds empirical quantitative and qualitative support for the proposed hypotheses. In different quadrants of the ISF, companies were found to use different types of IS-enabled sustainability initiatives in different patterns to enable sustainability strategy.*

Conclusions: *The study opens the IS box to provide further theoretical and empirical insights on how companies combine IS and business resources to develop different types of IS-enabled sustainability initiatives to help them address sustainability (both environmental and social) across the ISF. The study is among early IS research that adopts GRI reports as data source and presents a method for extracting GRI data for IS and sustainability research. Researchers and practitioners can both find the study's findings instructive.*

Keywords: Sustainability, Green IS, Sustainable IS, GRI report, Integrated Sustainability Framework.

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Introduction

Over the last decades, climate change and increasing measures of inequality such as the Gini Index have made sustainability a key business priority. Even during the height of the COVID-19 pandemic in 2020, assets managed by sustainability focused investment funds that abide by environmental, social, and governance principles (ESG funds) more than doubled in a year, surpassing 1 Trillion US Dollars in August, 2020 (Adamczyk, 2021; Meredith, 2020). ESG funds were also reported to outperform conventional investment funds with huge potential growth (Adamczyk, 2021). Business research has also found that while challenges abound, companies that truly embrace sustainability over the long-term outperform their counterparts in all three dimensions (environmental, social, and financial) of the triple bottom line (TBL) (Busch & Friede, 2018; Eccles et al., 2014; Flammer et al., 2019).

Since the late 2000s, Information Systems (IS) practitioners and researchers have increasingly focused their efforts on studying IS's contribution to address sustainability (Elliot & Webster, 2017; Singh & Sahu, 2020). IS research has acknowledged the significant role that IT infrastructure usage plays in reducing companies' environmental impacts (Green IT) and the significant role that information systems play in enabling environmental sustainability initiatives across a firm and its partners (Green IS) (Elliot & Webster, 2017; Sedera et al., 2017). Based on the Resource Based View (RBV), business and IS scholars have argued that companies could engage in a wide range of business activities to develop sustainability capabilities, defined as a firm's capacity to effectively coordinate bundles of complex IS and business resources (human and non-human resources) to achieve sustainability goals, delivering sustainable values to its stakeholders and gaining sustained competitive advantage (Dao et al., 2011; Dzhengiz & Niesten, 2020).

Expanding on earlier work (Dao & Abraham, 2018; Dao et al., 2011; Loeser et al., 2017), we develop and empirically examine hypotheses on how different types of IS-enabled sustainability initiatives (Infrastructure, Automate, Informate, Transform), defined as assemblage of IS and complementary business resources that are deployed to accomplish specific sustainability objectives, are used to address social and environmental sustainability in the four quadrants of the Integrated Sustainability Framework (ISF). IS-enabled sustainability initiatives data were collected for six leading sustainable companies in three industries with different levels of IT/IS use intensity. Our data sources were the companies' Global Reporting Initiative (GRI) reports between 2009 and 2015. Our hypotheses were largely supported using non-parametric statistical analysis (Friedman test) and the multiple-case study research method (Yin, 2013). In doing so, the study aims at answering the research question: *"How do firms use different types of IS-enabled sustainability initiatives to drive sustainability strategy in the four quadrants of the ISF?"*

Our study contributes to IS and business sustainability literature in several ways. First, IS research on sustainability so far has tended to develop models that pertain to specific cases, resulting in limited overarching theoretical and empirical understanding of how companies integrate IS resources with complementary business resources to develop capabilities to address sustainability (Loeser et al., 2017; Vidmar, et al., 2021). Using RBV and ISF as the theoretical foundation, our research opens the IS box to provide further theoretical and empirical insights (both quantitatively and qualitatively) on how companies combine IS and business resources to develop different types of IS-enabled sustainability initiatives to help them address sustainability and maintain sustained competitive advantage. Our study also provides further insight on how to align IS strategy with the situational context for specific sustainability objectives across the quadrants of the ISF. Such insights have implications for both IS and business sustainability literature and practice.

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Secondly, IS research on sustainability so far has mostly focused on environmental aspects of sustainability (e.g. Gholami et al., 2016; Singh & Sahu, 2020). To the best of our knowledge, there is a lack of theoretical and empirical insights on how IS could help address sustainability holistically, concurrently paying attention to Environmental, Social, and Financial aspects of the TBL. Our research helps fill this knowledge gap by studying companies IS-enabled sustainability initiatives that address both environmental and social sustainability. Additionally, our study is among early IS research that adopts GRI reports data and presents a method for extracting rich IS-enabled sustainability initiative data from GRI reports for IS scholars interested in studying information systems and sustainability.

The remaining sections are structured as follows. The next section provides a brief review of the IS and sustainability literature. The third section introduces the hypotheses on the patterns of how IS-enabled sustainability initiatives are used to drive sustainability strategy in the four quadrants of the ISF, based on RBV's and ISF's theoretical foundation. Section four discusses our methodology and data collection process. Section five presents statistical results from our non-parametric hypothesis testing using data collected from the cases. Section six discusses qualitative insights and analyses from the cases. The seven and eight sections conclude the manuscript by discussing our findings and its implications for research and practice and suggesting avenues for future research on IS and sustainability.

IS and Sustainability

Since the late 2000s, IS research has increasingly examined the role of IS in helping business addressing sustainability. Research has examined both individual (Leung et al., 2019) and organizational behavior (Chua et al., 2019). Research and practice moved beyond Green IT to put more focus on Green IS, which examined how information systems could be used to help organizations improve their sustainability performance by embedding IS in their pollution prevention, product stewardship, and business transformation activities (Gholami et al., 2013; Hedman & Henningson, 2016; Singh & Sahu, 2020).

While progress in Green IS research has expanded our understanding of the role of IS in helping firms become more sustainable, two gaps in our knowledge exist that this current study attempts to study. First, there is a lack of overarching theoretical understanding and empirical examination of how IS enables companies to develop capabilities to address sustainability. Green IS research has been categorized into conceptual, analytical, design oriented and impact-oriented research (Gholami et al., 2016). Much of the conceptual and analytical research focuses on identifying the factors that contribute to firms' adoption of Green IS such as innovativeness (Benitez-Amado et al., 2010), environmental awareness and industry norms (Hu et al., 2016), functional affordances (Seidel et al., 2013), IS-environmental absorptive capacity (Cooper & Molla, 2017) and green leadership (Tan et al., 2015). Additionally, such studies tend to focus on requirements for specific types of Green IS such as energy systems or specific environmental challenges such as energy consumption or greenhouse gas emissions (Elliot & Webster, 2017; Ryoo & Koo, 2013; Watson et al., 2010). As a result, Green IS studies have tended to have developed models pertaining to specific cases, thus are limited in providing an overarching theoretical understanding or empirical examination of IS-enabled capabilities to address sustainability (Loeser et al., 2017; Vidmar, et al., 2021).

Secondly, most Green IS research has mainly studied environmental aspects of sustainability (e.g. El Idrissi & Corbett, 2016; Gholami et al., 2016; Singh & Sahu, 2020). While there exists a rich tradition of research of social issues in IS research (e.g. de Kruijf, 2015; Shethia & Techatassanasoontorn, 2019), the two areas of environmental and social IS research rarely intersect. Meanwhile, recent research has argued that because of the intertwinement of social and environmental sustainability issues, it is critical that they are addressed concurrently in

both research and practice (Abraham & Dao, 2019; Dao et al., 2011; Peters et al., 2019; Sedera et al., 2017; Wiengarten et al., 2017). Therefore, some IS scholars have argued for IS research and practice to adopt a more holistic view of sustainability that includes both environmental and social sustainability (Dao et al., 2011; Seidel et al., 2017). Based on our own review of the IS literature, little IS research has provided theoretical and empirical insights on this area of research, Sustainable IS, that would enable companies to use IS resources to address sustainability holistically.

Our research helps fill such knowledge gaps as follow. RBV and ISF could provide a theoretical foundation for empirical examinations on how IS resources are used to enable companies to address sustainability holistically. Based on RBV, business and IS scholars have argued that companies could effectively coordinate bundles of complex IS and business resources (human and non-human) to develop sustainability capabilities that could help them concurrently achieve sustainability goals and maintain sustained competitive advantage since such capabilities are rare, non-substitutable, and causally ambiguous (Dangelico et al., 2017; Dao et al., 2011; Dzhengiz & Niesten, 2020; Eccles & Serafeim, 2013).

IS scholars have argued that the combination of IS and complementary business resources to enable sustainability capabilities can be reflected in IS-enabled sustainability initiatives, defined as assemblage of IS and complementary business resources that are deployed to accomplish specific sustainability objectives (Dao et al., 2011; Loeser et al., 2017). Such initiatives enable firms to engage in a wide range of IS-enabled business activities such as business process efficiency improvement, business process reengineering, digital transformation for sustainability, supply chain partner collaboration, stakeholders engagement, etc. that help them address sustainability effectively (Loeser et al., 2017; Vial, 2019, etc.).

The ISF (Dao et al., 2011) proposes that companies would use different types of IS resources differently to develop sustainability capabilities in the framework's four quadrants. In the next section, we will use RBV and the ISF as theoretical foundation to develop hypotheses on how different types of IS-enabled business initiatives are used to address sustainability objectives in the four quadrants of the ISF that will be empirically examined in our study. Additionally, we include both social and environmental initiatives in our theorizing and data collection in order to address sustainability in a holistic way.

Research Hypotheses

The ISF defines four quadrants of sustainability and provides theoretical arguments that different types of IS resources could have distinctive impacts on organizational performance and thus could be used by companies in distinct ways to develop sustainability capabilities to achieve different sustainability performance objectives (Dao & Abraham, 2018; Dao et al., 2011). Additionally, as business managers make decisions on IS investments to enable sustainability initiatives, they usually have a variety of operational and strategic purposes with regards to how/when/where such investments' benefit should be realized in terms of helping to improve their businesses' sustainability performance. A popular framework that has been used to differentiate IS investments is the IS strategic role framework that categorizes IS-enabled initiatives as performing automate, informate, transform, or infrastructure roles (Aral & Weill, 2007; Chae et al., 2018; Dao et al., 2011; Yin et al., 2020; Zuboff, 1988).

Using RBV and the ISF as theoretical foundation, we hypothesize that different types of IS-enabled initiatives (automate, informate, transform, or infrastructure) could be used by companies in different patterns to achieve sustainability goals in different quadrants of the ISF and gain sustained competitive advantage. Figure 1 illustrates the ISF with our hypothesized use of IS-enabled sustainability initiatives. The Appendix provides further detail definitions of

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Automate/Informate/Transform/Infrastructure IS-enabled sustainability initiatives for our data coding.

	Internal	External
Today	**Quadrant 1** *-Sustainability Strategy:* ● Prevent pollution via optimizing operation, to reduce cost and impacts on the environment. ● Create organizational culture aimed towards sustainability, improve employee management practices within firms. - *Payoff:* Reduced costs, reduced environmental impacts, increased profitability, reduced risk, improved employee working conditions. *-IS-enabled initiatives hypothesized to be used more frequently:* ● Infrastructure's technical platform optimization. ● Automate and informate initiatives.	**Quadrant 2** *- Sustainability Strategy:* ● Improve extended supply chain to reduce pollution through material and processes choices and closed-loop supply chain ● Extend organizational culture aimed towards addressing sustainability issues affecting both internal and external stakeholders. - *Payoff*: Reputation and legitimacy, reduced environmental impacts, more socially and environmentally sustainable supply chain, increased competitive advantage. *-IS-enabled initiatives hypothesized to be used more frequently* ● Infrastructure integration. ● Informate initiatives.
Tomorrow	**Quadrant 3** *- Sustainability Strategy:* ● Develop capabilities that enable radical clean technologies and processes that help solve social and environmental issues. - *Payoff*: Innovation, strategic positioning, better and more sustainable products/services. *-IS-enabled initiatives hypothesized to be used more frequently* ● Infrastructure flexibility. ● Transform initiatives.	**Quadrant 4** *- Sustainability Strategy:* ● Include core sustainability capabilities in all products, processes, and supply chains. ● Sustainability vision: Open new, previously ignored dialogues with stakeholders to solve social issues and locate growth opportunities. - *Payoff:* Growth trajectory. *-IS-enabled initiatives hypothesized to be used more frequently* ● Informate initiatives.

Figure 1 - Integrated Sustainability Framework and Hypothesized Use of Initiatives

Quadrant 1: Internal-today

Within this quadrant, firms focus on achieving sustainability goals by optimizing their current internal operation by engaging in activities such as continuous internal process improvements, improving employee involvement and safety and health, waste reduction, energy conservation, etc. (Kleindorfer et al., 2005; Sedera et al., 2017). In doing so, firms could improve the sustainability impacts of their current business operation as well as develop win-win conditions for them and their internal stakeholders (i.e. employees) (Dao et al., 2011; Eccles et al., 2014).

IS-enabled sustainability initiatives could enable firms to address such sustainability goals. First, IT Infrastructure optimization initiatives such as green data centers and energy efficient equipment can cut energy costs and reduce pollution. Automate initiatives like robots can improve worker safety and improve operational efficiency. Additionally, informate initiatives

that provide better and faster information to employees and managers like dashboards and enterprise portals could improve both environmental performance such as waste management and social performance such as employee wellness. For example, during the COVID-19 pandemic, organizations encouraged employees and students to install mobile apps that help them communicate COVID information and trace contacts.

From the RBV perspective, these initiatives, developed by combining IS and business resources, could be valuable and difficult to substitute or imitate. For example, employees who possess firm-specific knowledge are better skilled in utilizing the initiatives' support to make effective sustainability decisions. Similarly, cross-functional teams with firm-specific firm knowledge and collaboration experience will excel in utilizing IS initiatives to deliberate different design alternatives for sustainability. Such experienced employees and teams are difficult to be imitated by competitors. We thus expect that companies will focus on using IT infrastructure, automate, and informate IS-enabled sustainability initiatives to help them address sustainability issues within quadrant 1.

> ***Hypothesis 1:*** *Within quadrant 1 of the ISF, companies will be observed to proportionally use more infrastructure, automate and informate IS-enabled sustainability initiatives than transform IS-enabled sustainability initiatives.*

Quadrant 2: External-today

Within this quadrant, the sustainability focus shifts to collaborating with external stakeholder (supply chain partners, customers, etc.) to deliver sustainability values by developing capabilities to lower environmental impacts, address social issues related to firms' internal and external stakeholders, reduce cost, increase profitability, and enhance legitimacy and reputation (Dao et al., 2011).

Closed IS-enabled collaboration between firms and their supply chain partners enable them to improve sustainability performance across the supply chain. For example, multiple leading sustainable companies such as Nike and Apple have successfully developed environmental and social sustainability standard indexes and use informate IS-enabled initiatives such as web portals, inter-enterprise integrated systems to enable them and their supply chain partners (e.g. suppliers and retailers) to share information and collaborate to adhere to such standards across the supply chain. Other informate IS-enabled initiatives such as websites would also help companies better communicate with other external stakeholders such as consumers, regulators, conscientious investors, etc. about their sustainability performance, enhancing their reputation.

To enable such collaboration, a firm's infrastructure will need to be well integrated with its partners'. From the RBV perspective, these collaboration capabilities enabled by informate and infrastructure integration initiatives are deeply embedded organizational processes, are firm specific and difficult to be imitated, thus the enhanced sustainability performance and reputation gained from such initiatives are difficult to replicate and help firms sustain their competitive advantage (Rai et al., 2006; Singh & Teng, 2016). Therefore, we expect that companies will focus on using IT infrastructure and informate IS-enabled sustainability initiatives to help them address sustainability issues within quadrant 2.

> ***Hypothesis 2:*** *Within quadrant 2 of the ISF, companies will be observed to proportionally use more infrastructure and informate IS-enabled sustainability initiatives than automate and transform IS-enabled sustainability initiatives.*

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Quadrant 3: Internal-tomorrow

Within this quadrant, companies focus on developing capabilities that enable them to leapfrog industry standards, which could transform the industry's prevalent product portfolio, business practices and processes, potentially enhancing the companies' sustainability performance and competitive advantage (Dao et al., 2011). For example, Tesla has successfully disrupted the automotive manufacturing industry with its electronic vehicles and direct sales business model, significantly contributing to the reduction of environmental impacts of the automotive industry and establish the company as a leading company in the industry. Sustainability capabilities developed in this quadrant would have both social and environmental sustainability impacts.

In this quadrant, companies could use transform IS-enabled initiatives to enable them to develop sustainability capabilities. They could be exemplified by multiple digital transformation initiatives such as remote vehicle services (in the case of Tesla's Mobile Services), Netflix's new business model of streaming services, digital reality devices, supply chain blockchain initiatives, etc. (Vial, 2019). Meanwhile, companies' infrastructure needs to be flexible enough to enable and timely adapt to new transform initiatives. For example, United Parcel Service's (UPS) flexible IT architectures enable UPS to integrate its data and connect its systems with customers' applications, providing real-time inventory information that can be leveraged by customers to improve inventory management, asset efficiencies, and market responsiveness (Rai et al., 2006).

From the RBV perspective, sustainability capabilities developed via transform initiatives enable companies to reposition their internal skill sets for the development and exploitation of future markets, which are critical in enabling firms to address sustainability holistically and achieve sustained competitive advantage (Hart & Milstein, 2003; Vial, 2019). Additionally, flexible IT infrastructure to enable such transform initiatives needs to be carefully planned for and developed over time. This path dependent process creates capabilities that are difficult to be imitated (Chen et al., 2017; Ray et al., 2005). Therefore, we expect that companies focus on using IT infrastructure flexibility and transform IS-enabled sustainability initiatives to help them address sustainability issues in quadrant 3.

> ***Hypothesis 3:*** *Within quadrant 3 of the ISF, companies will be observed to proportionally use more infrastructure and transform IS-enabled sustainability initiatives than automate and informate IS-enabled sustainability initiatives.*

Quadrant 4: External Tomorrow

In this quadrant, firms focus on the future and place their sustainable growth within their social context (Dao et al., 2011). Firms addressing sustainability in this quadrant thus will pursue strategy to develop a sustainability vision about the shared roadmap of sustainable growth and engage with outside stakeholders in sensing unmet opportunities and addressing sustainability issues of the future. Informate initiatives can support the development and communication of this vision. For example, Unilever uses crowdsourcing to invite partners to help design new sustainable products and processes. In another example, Johnson and Johnson has used multiple mobile apps to reach out and serve the needs of traditionally underserved markets such as expectant mothers in India.

Additionally, companies could also build relationships and share sustainability vision across its supply chain to be embedded in a strategy of all supply chain members to ensure the entire chain becomes more sustainable over time. This would be accomplished by using informate initiatives to enable collaboration sustainability metrics gathering and continuous improvement that would ensure strategic sustainability alignment among supply chain partners.

From the RBV perspective, sustainability is a path dependence process since companies that have developed capabilities to develop clean technologies and processes could now integrate them into core capabilities that are included in products, processes, and supply chains for long-term sustainability (Hart & Milstein, 2003). Such capabilities that have been enabled by IS sustainability initiatives are difficult to be imitated, giving the companies potential sustained competitive advantage (Dao et al., 2011; Rai et al., 2006; Singh & Teng, 2016).

> ***Hypothesis 4:*** *Within quadrant 4 of the ISF, companies will be observed to proportionally use more informate IS-enabled sustainability initiatives than infrastructure, automate, and transform sustainability initiatives.*

Methodology

Multiple-case Study Research Method

To empirically examine the hypotheses, we conduct an exploratory multiple-case study to provide "an empirical enquiry that investigates a contemporary phenomenon in depth and within its real-life context." (Yin, 2009, p.18). The multiple-case study method enables us to achieve several objectives. First, data coded from the cases, as described later, allow us to use non-parametric analysis of variance, the Friedman test, to statistically test our hypotheses. Secondly, exploring individual cases' qualitative data allows us a more granular perspective and helps us provide a sustainability narrative for each company and industry studied. Additionally, the multiple-case approach allows us to replicate the examination across cases to see if subsequent cases confirm findings drawn from previous cases, ensuring a wider coverage and applicability of the findings in multiple cases (Bingham & Eisenhardt, 2011; Sarker et al., 2013). We also adopt the approach of theory building from cases (Einsenhardt & Graebner, 2007) to both deductively test the hypotheses and inductively suggest refining the hypotheses based on our findings. This integrative approach has also been used in this field by Corbett et al. (2018). Case studies have also been used by previous research on IS and sustainability (Cooper & Molla, 2017; Gholami et al., 2013; Hedman & Henningsson, 2016; Seidel et al., 2013; Yang et al., 2020).

We collected data for our case companies from their Global Reporting Initiative (GRI) reports. Other work has linked the rise of Green IS to the social innovation of sustainability reporting, and GRI in particular (Carberry et al., 2019). We decided to use GRI reports as our data source for two main reasons. First, GRI has recently emerged as a reliable source of data for IS and sustainability research (Abraham & Dao, 2019; Deng et al., 2017; Watts, 2016). Second, using GRI reports allows us to conduct multiple-case studies of firms across multiple industries since GRI reports can be easily collected from the GRI database.

Data Collection and Coding

We adopt a "theoretical sampling" approach used in previous studies in choosing as our cases six companies across three different industries. We decided to pick three industries that have been used in previous research as having distinct levels of IT/IS intensity of high, intermediate, and low, as rated by academic and industry IT experts, based on how much each industry's processes and products/services offering could be transformed by IT (Chatterjee et al., 2001). The chosen industries are the pharmaceutical/biotechnology industry, the food/beverages industry, and the heavy equipment manufacturing industry. IS/IT in these industries have also been assessed to play, respectively, transform, informate, and automate strategic role, reflecting distinct industry-level contexts within which IS/IT deployment occurs (Chatterjee et al., 2001; Yin et al., 2020). This approach of theoretical sampling has been used in multiple studies, which has been argued to help maximize the chances of detecting the hypothesized

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relationships while ruling out chances that findings are due to either random noise or systematic bias in the data (Chae et al., 2018; Yin et al., 2020; Zmud et al., 2010).

In order to collect IS-enabled sustainability initiatives data, we needed to examine GRI reports of focal companies to extract discussions of IS-enabled initiatives and conduct a laborious content coding process to choose and code the discussion of these initiatives. Therefore, to balance the breadth and depth of our data and the laborious data collection process, we decided to collect data for six companies, two from each industry, across seven years from 2009 to 2015, a period length that has been adopted by previous research (Chae et al., 2018; Yin et al., 2020). 2009 was the first year that GRI reports were available in the GRI database. For each industry, we chose two leading sustainable companies that were listed in highly respected rankings of most sustainable global companies, Corporate Knights Global 100 and S&P Dow Jones Sustainability Index. The chosen companies are Johnson and Johnson (J&J) and Biogen for the pharmaceutical industry, Coca Cola and General Mills for the food and beverages industry, and Volvo and Caterpillar for the heavy manufacturing industry.

The companies' GRI reports over a seven-year period from 2009 to 2015 were downloaded from the GRI database. The two authors examined the GRI reports using a broad set of keywords. After having examined the results, we decided to use a final list of keywords that managed to capture all initiatives we intended to collect while reducing the number of non-relevant discussion. The chosen keywords were "IT", "ICT", "Information", "Information Systems", "Information technology", "Internet", "system", "Information". Paragraphs including these search terms that discuss IS-enabled initiatives addressing sustainability were collected. Each discussion of IS-enabled sustainability innovative initiative was coded into two categories: 1) the role of the IS (infrastructure, automate, informate, or transform) and 2) the strategic focus or quadrant of the ISF that the IS-enabled initiative addresses (Quadrants 1 to 4).

The authors developed the initial coding rules (see Appendix) and independently coded one company's data. After the coding, we met to assess agreement regarding the codes assigned, resolved disagreements, and refined the coding rules. Coding then commenced for the next firm. This approach maintained intra- and inter-coder consistency throughout the process. Inter-rater reliability was assessed using Cohen's Kappa with results >0.7, reflecting excellent inter–rater reliability.

We adopted a phrase approach to our data collection. First, data were collected from the two pharmaceutical company cases (J&J and Biogen), an industry with the highest level of IS intensity. After having coded and assessed that data from the first two companies appeared to be supportive of the hypotheses, we added to our study food/beverages cases Coca Cola and General Mills, an industry that has middle level of IS intensity, using the same coding scheme. After assessing that results from the next two cases provided additional value, we decided to add heavy equipment manufacturing cases Volvo and Caterpillar to our study, the least IS intensive industry of the three industries chosen.

We recruited a research assistant to help with data collection and coding of Volvo and Caterpillar. The research assistant went through "coding training" with one author using collected and coded data of the first four cases. Once inter-rater reliability reached a satisfactory level (Cohen's Kappa>0.7), the assistant finished the coding on his own of Volvo and Caterpillar data.

Statistical Analysis

With 145 initiatives collected from six companies, the small set of coded data does not allow us to use parametric tests to test our hypotheses. We decided to use the Friedman test to test our hypotheses. The Friedman test is a non-parametric analysis of variance using several related samples using ranked data (Conover, 1999). It allows us to evaluate the statistical significance of differences among proportions of different types of IS-enabled sustainability initiatives used within each quadrant of the ISF. This enables us to evaluate our hypotheses that argue that within each quadrant certain types of IS-enabled sustainability initiatives are proportionally used more frequently than other types.

In the following section, we will describe our non-parametric empirical examination of the hypotheses using coded data and examine the qualitative cases in more detail to provide intimate stories about the case companies' use of different types of IS-enabled sustainability initiatives to address sustainability issues in the four quadrants of the ISF. Table 1 presents the number of coded IS-enabled initiatives for all cases.

Table 1 - Number of IS-enabled sustainability initiatives by type and quadrant

Types/Quadrants	Q1	Q2	Q3	Q4
Infra	13 (22.4%)	2 (3.1%)	0 (0.0%)	0 (0.0%)
A	18 (31.0%)	11 (17.2%)	0 (0.0%)	0 (0.0%)
I	27 (46.6%)	50 (78.1%)	1 (14.3%)	9 (56.3%)
T	0 (0.0%)	1 (1.6%)	6 (85.7%)	7 (43.7%)
Grand Total	**58 (100%)**	**64 (100%)**	**7 (100%)**	**16 (100%)**

Non-parametric Hypothesis Testing

To examine the differences of proportions of different types of IS-enabled sustainability initiatives used within each quadrant of the ISF, a separate Friedman test is run for each quadrant. First, for each firm within a quadrant, the number of infrastructure-, automate-, informate-, and transform-enabled sustainable initiatives were ranked against each other for rank numbers 1, 2, 3, or 4. Average ranks were used in case of ties. The ranks of the four types of initiatives were then summed up. Table 2 represents the summed rank data.

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Table 2 - Summed ranks of initiatives and Friedman test statistics				
Types/Quadrants	**Q1**	**Q2**	**Q3**	**Q4**
Summed rank of initiatives*				
Infra	14	18	12.5	12.5
A	14	16	12.5	12.5
I	10	6	11	8
T	22	20	4	7
Friedman Test Statistics				
T_2 test statistic	4.13	14.5	33	2.68
T_2 benchmark at α=0.05	3.29	3.29	3.86	3.86
Multiple comparison statistic	5.88	3.88	1.68	4.23

*: The smaller the rank score, the greater the number of signals.

Friedman test statistics are assessed in two steps. In the first step, for each quadrant, statistics are calculated to assess the null hypothesis of whether individual ranking of different types of initiatives are equally likely observed. In the second step of multiple comparisons, statistics are retrieved to assess whether the differences in individual pairs of ranks of initiative types are significant. The following paragraphs explain how the two steps were done in more detail for quadrant 1 initiatives to evaluate Hypothesis 1.

Hypothesis 1 argues that within quadrant 1, companies will be observed to proportionally use more infrastructure, automate and informate IS-enabled sustainability initiatives than transform IS-enabled sustainability initiatives. For the Friedman test's first step of null hypothesis testing, test statistic T2 is calculated as 4.13 (T2 has F-distribution with degrees of freedom k1=3 and k2=15). At α=0.05, the critical region corresponds to all values of T2 that are greater than 3.29. Since the calculated T2 (4.13) is greater than 3.29, we can conclude that the null hypothesis of equal ranks for frequency of four types of initiatives is rejected. Therefore, there is a tendency that some types of initiatives may be used proportionally more than others by companies within quadrant 1.

In the Friedman test's second step of multiple comparisons, the multiple comparison statistic at α=0.05 (t0.05) is calculated. For quadrant 1, t0.05= 5.88 (see Table 2). If the rank-difference between summed ranks of two types of initiatives is greater than t0.05 value, we could conclude that difference in proportions of the two types of initiatives is statistically significant.

The rank-difference between summed rank of infrastructure initiatives (14) and transform initiatives (22) is 22-14= 8 (greater than 5.88, see Table 2). Therefore, we can conclude that infrastructure initiatives were significantly used proportionally more than transform initiatives in quadrant 1. Similarly, the rank-difference between summed ranks of transform initiatives (22) and automate (14) initiatives, and between transform initiatives and informate initiatives (10) are 22-14=8 and 22-10=12, respectively, which are both greater than 5.88. Thus we can conclude that infrastructure, automate, and informate initiatives were proportionally used more than transform initiatives in quadrant 1, supporting Hypothesis 1.

The same approach was used for testing Hypothesis 2 for quadrant 2, which argues that in quadrant 2 companies use proportionally more infrastructure and informate initiatives than automate and transform initiatives. For the Friedman test's null hypothesis testing step, test statistics T2 is 14.5 which is greater than T2 benchmark value of 3.29. Therefore, the null hypothesis of equal rank among all types of initiatives is rejected. For the second step of the multiple comparisons, the calculated multiple comparison statistic t0.05 is 3.88. The differences between summed rank of informate initiatives (6) and summed rank of automate initiatives (16) and transform initiatives (20) initiatives are 10 and 12, respectively. Both are greater than the multiple comparison statistic of 3.88 (see Table 2). Therefore, we can conclude that informate initiatives were used proportionally more than automate and transform initiatives in quadrant 2. However, the difference between summed rank of infrastructure initiatives (18) and summed rank of automate initiatives (16) and transform initiatives (20) are less than 3.88. Thus, we cannot conclude that infrastructure initiatives were used proportionally more than automate and transform initiatives in quadrant 2. These findings support Hypothesis 2 for informate initiatives, but not for infrastructure initiatives.

Hypothesis 3 argues that in quadrant 3 companies use proportionally more infrastructure and transform initiatives than automate and transform initiatives. Following the same approach, null hypothesis of equal rank among initiative types is rejected (T2 =33, which is greater than 3.86 benchmark). The differences between the summed rank of transform initiatives (4) and summed rank of automate initiatives (12.5) and informate initiatives (11) initiatives are 8.5 and 7, respectively. Both are greater than the multiple comparison statistic of 1.68 (see Table 2). Therefore, we can conclude that transform initiatives were proportionally used more than automate and informate initiatives. Since there were no infrastructure initiatives used in this quadrant, we cannot conclude that infrastructure initiatives are proportionally used more than automate and informate initiatives in quadrant 3. *These findings support Hypothesis 3 for transform initiatives, but not for infrastructure initiatives.*

Hypothesis 4 argues that in quadrant 4 companies use proportionally more informate initiatives than the other three types of initiatives. While the Friedman test's null hypothesis is not rejected (T2 test statistic=2.68 is smaller than benchmark value 3.86), the lack of infrastructure and automate initiatives observed in this quadrant provides some *support for Hypothesis 4 for informate initiatives over infrastructure and automate initiatives, but not for informate initiatives over transform initiatives.*

Findings from Qualitative Data

This section discusses the cases in depth by industry. For each industry, we examine qualitatively how companies' using different types of IS-enabled sustainability initiatives within each quadrant of the ISF align with our hypotheses as well as examples of particular initiatives that are implemented within the quadrants. By doing so, our multiple-case approach helps provide further insight, beyond statistical analysis results, on the nature of the IS-enabled sustainability initiatives that companies within the three industries use to address sustainability within the ISF. This approach also allows us to see if the hypotheses are applicable across individual cases.

Pharmaceutical Industry

Among the three industries, pharmaceutical is the most IS intensive industry. Therefore, we expected companies in this industry to be more active, compared to the other two industries, in using IS-enabled sustainability initiatives to address sustainability issues. Data collected from GRI reports show that both companies are committed to sustainability holistically. J&J is a leading pharmaceutical company and Biogen is a leading biotechnology company Tables 3 and 4 include data on coded initiatives for J&J and Biogen.

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Table 3 - J&J's IS-enabled Sustainability Initiatives Data					
Year	**Q1**	**Q2**	**Q3**	**Q4**	**Grand Total**
2009					
A	1(Labor DB)				1
I	1	2		1(text4baby)	4
2009 Total	**2**	**2**		**1**	**5**
2011					
Infra	1 (Simplify IT)				1
I	2 (Risk tools)	4(Responsibility website)		1(MAMA)	7
2011 Total	**3**	**4**		**1**	**8**
2013					
A	3 (Driver data)				3
I	1 (Site DB)	1 (Brand websites)		1(Life-saving mobile info)	3
2013 Total	**4**	**1**		**1**	**6**
2014					
A		1			1
I	1 (Labor practices)	3 (Brand websites)		1(mMitra)	5
2014 Total	**1**	**4**		**1**	**6**
2015					
I	3 (Labor; training; Grievances)	1 (Haiti EMR)		1(Grassroots)	5
2015 Total	**3**	**1**		**1**	**5**
Aggregate					
Infra	1				**1**
A	4	1			**5**
I	8	11		5	**24**
Grand Total	**13**	**12**	**0**	**5**	**30**

Table 4 - Biogen's IS-enabled Sustainability Initiatives Data					
Year	**Q1**	**Q2**	**Q3**	**Q4**	**Grand Total**
2009					
Infra	1(Green DC)				1
I	2 (EMS; EHS)				2
2009 Total	**3**				**3**
2012					
Infra	1(Cooling)				1
2012 Total	**1**				**1**
2013					
Infra	1(Cooling)				1
T			1(R&D IT Strategy)		1
2013 Total		**1**	**1**		**2**
2014					
Infra	1(Cloud servers)				1
I	1(EHS+S updates)			2(Micro8; Atlas DB)	3
T			2(Digital healthtech; Data mining)	1(Wearables)	3
2014 Total	**2**		**2**	**3**	**7**
2015					
I		2(Risk Assessment; Data mining)	1(SHIFT-Sustainability, Help, Information, Frameworks and Tools)	2(MSPT; mySidekick; iPad-based tools and app for health outcome tracking)	5
T				1(MSPT)	1
2015 Total		**2**	**1**	**3**	**6**
Aggregate					
Infra	4				4
I	3	2	1	4	10
T			3	2	5
Grand Total	**7**	**2**	**4**	**6**	**19**

J&J focused most of its initiatives (25/30) on today's quadrants (Q1 and Q2). J&J implemented 13 Q1 initiatives. Among them, one was an Infrastructure initiative (Infra), standardizing and simplifying IT systems used for quality and compliance. Four initiatives were automate (A). In 2009, a new workforce statistics data management system was built (A, Q1). In 2013, they launched in-vehicle monitoring systems to address high risk driving behaviors (A, Q1). J&J's largest number of Q1 initiatives were Informate (I) (8/13). Examples of such informate initiatives include employee management systems, websites to increase employees' access to information on responsibility and performance, enterprise-level global training, internal labor relation systems and a Global IS database to locate sustainable sites. *The use of infrastructure, automate, and informate initiatives by J&J in Q1 supports Hypothesis 1.*

J&J implemented about the same number of Q2 initiatives (12), compared to 13 of its Q1 initiatives. Besides one automate initiative that automated the sharing of customer supply chain index, the remaining 11 initiatives were informate. For example, J&J implemented websites to engage stakeholders, developed systems and websites that enabled all its brands to share sustainability information with customers, or developed systems that enable people

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to gain access to health-related information. (I, Q2). *Such use of informate initiatives supports Hypothesis 2.*

Besides its focus on Q1 and Q2, J&J implemented five informate initiatives to address Q4 sustainability issues. For example, an initiative called mMitra was used to send information to mothers in India via text. Also, a system was added to connect grassroots entrepreneurs to health data. *This also supports Hypothesis 4.*

Unlike J&J's focus on today quadrants (Q1 and Q2), Biogen used half of its initiatives on today quadrants (7 Q1 and 2 Q2 initiatives) and the remaining half on tomorrow quadrants (4 Q3 and 6 Q4 initiatives). For Q1, Biogen implemented four Infra initiatives, including green data center, cloud based and right sized servers. Additionally, Biogen implemented three informate initiatives for Q1, such as Health and Safety Management (EHS) and Environmental Management Systems (EMS) (I, Q1) to provide better information to its employees to improve the company's sustainability performance.

For Q2, Biogen implemented two informate initiatives, including applications and tools such as MySidekick app to allow patients to keep track of their health (I, Q2). We did not observe any automate initiatives implemented by *Biogen in Q1 and Q2. Biogen's initiatives support Hypotheses 1 and 2 for infrastructure and informate initiatives.*

There is an increase in the number of initiatives implemented in subsequent years (from two initiatives in 2013 to seven in 2014 and six in 2015) as well as a shift of more initiatives in tomorrow quadrants (Q3 and Q4). One and four informate initiatives were used for Q3 and Q4, respectively. For example, the company implemented initiatives that develop online platform and use datamining to help the company consolidate corporate sustainability and reach unserved/underserved communities (I, Q4). Biogen's focus on tomorrow quadrants also resulted in more transform (T) initiatives implemented during the period studied. For example, Biogen adopted internal analytics, created new global and digital health tech groups (T, Q3) and provided patients with wearables and personalized medicine (T, Q4). *Qualitative data of Biogen supports Hypotheses 3 and 4.*

Food and Beverages Industry

As described earlier. Once we observed interesting findings from pharmaceutical cases, we proceeded with the food and beverages industry cases of Coca Cola and General Mills, which are expected to be less IS intensive, to see if companies in a less IS-intensive industry also use IS in enabling their sustainability in the same ways described in the hypothesis' logic. Table 5 and 6 present Coca Cola's and General Mills' coded data, respectively.

Table 5 - Coca Cola's IS-enabled Sustainability Initiatives Data

Year	Q1	Q2	Q3	Grand Total
2010 &2011				
Infra	1(Intelligent lighting)			1
I	1 (Energy Meters)	1(Internet engagement)		2
2010 &2011 Total	**2**	**1**		**3**
2012				
Infra	2(Link to SAP; EMS)	1(Repair/Donate)		3
A	1(Data Entry)			1
I	1(M&T to SAP)	2(No Internet marketing to children)		3
2012 Total	**4**	**3**		**7**
2013				
Infra	2(EMS-55)			2
I	1(Carbon accounting)	1(No Internet marketing to children)		2
2013 Total	**3**	**1**		**4**
2014				
Infra	1(Low energy accreditation)			1
A	1(ASRS)			1
I	1 (Live energy data)	1(Infineo virtual tour)		2
T			1(Lean Startup)	1
2014 Total	**3**	**1**	**1**	**5**
Aggregate				
Infra	6	1		7
A	2	5		7
I	4			4
T			1	1
Grand Total	**12**	**6**	**1**	**19**

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Table 6 - General Mills' IS-enabled Sustainability Initiatives Data				
Year	**Q1**	**Q2**	**Q3**	**Grand Total**
2010				
Infra	2(ComputerWorld Best Place to work; Virtual Collaboration)			2
I	2 (LifeClinic employee Stations)	1 (Connect Online)		3
2010 Total	**4**	**3**		**5**
2011				
I	2 (EMS; energy meters)	3(Betty Crocker Apps)		5
2011 Total	**2**	**3**		**5**
2012				
I	1(Global Safety Tracking)			1
2012 Total	**1**			**1**
2013				
I	1(GSTEMS updated)	1(Nature Valley website)		2
2013 Total	**1**	**1**		**2**
2014				
Infra		1(Barcode for donations)		1
I		4(Traceability of sources; #1 rank political accountability)		4
2014 Total		**5**		**5**
2015				
I	3(GSTEMS)	1 (Global Traceability)		4
T			1(Integrated values)	1
2015 Total	**3**	**1**	**1**	**5**
Aggregate				
Infra	2	1		3
I	9	10		19
T			1	1
Grand Total	**11**	**11**	**1**	**23**

Both companies focus their initiatives on today quadrants (Q1 and Q2). Each has just 1 initiative in tomorrow internal operations (Q3) and none in tomorrow external operations (Q4). The two companies differ in that while Coca Cola focuses most of its initiatives on Q1 (12/19 initiatives), General Mills equally focuses on Q1 and Q2 (11/23 initiatives for each quadrant). This difference in sustainability strategy is reflected in the two companies' use of different IS initiative types as well.

Given its main focus on Q1, Coca Cola implemented multiple infrastructure, automate, and informate initiatives for this quadrant. The company implemented multiple infrastructure initiatives to optimize its current operation's efficiency such as installing intelligent lighting systems and energy management devices for coolers and vending machines, and linking energy and water monitoring systems to the SAP business system (Infra, Q1). For Q1, Coca Cola also used automate initiatives such as warehouse automation and developed a database to automate data entry at manufacturing and distribution sites (A, Q1). It used informate initiatives such a health monitoring website for employees and implementing a company-wide

carbon accounting system for both core operation' and value chain' carbon footprint (I, Q1). Coca Cola's initiatives support hypotheses 1, 2, and 3.

Meanwhile, General Mills mostly implemented informate initiatives (19/23) and equally used for both Q1 and Q2. For Q1, General Mills invested in informate initiatives such as a computerized truck routing system (I, Q1), employee wellness (I, Q1), energy meters on equipment (I, Q1) and a created and expanded a system to trace global safety and sustainability (GSTEMS) (I, Q1).

In later years, General Mills increased its efforts in implementing Q2 initiatives. In 2011, it offered new sustainable services for cooking at home and a Nature Valley website (I, Q2), and listing ingredients and sources (I, Q2). General Mills had one transform initiative when it adopted new company values (T, Q3). Qualitative data of General Mills supports Hypotheses 1, 2, and 3. Similar to the two pharmaceutical companies, Cocal Cola and General Mills implemented their IS-enabled sustainability initiatives to address all three aspects of sustainability holistically.

Heavy Manufacturing Industry

Surprisingly for an industry with the expected lowest level of IS/IT intensity the three industries, the companies actually implemented the most IS-enabled initiatives. Table 7 and 8 present Volvo's and Caterpillar' coded data, respectively.

Table 7 - Volvo's IS-enabled Sustainability Initiatives Data

Year	Q1	Q2	Q3	Q4	Grand Total
2010					
A	2 (feedback/ chemicals DB)				2
I	1 (GlobeSmart)	3 (CommuteGreen; CareTrack; ICS)			4
2010 Total	**3**	**3**			**6**
2011					
A	1 (SubsTrack)				1
I		1 (eLearning)			1
2011 Total	**1**	**1**			**2**
2012					
A		2 (Auto brake; Aqua)			2
I	1 (Web training)	4 (Dealer data; Fleet; driver attention; ICS)			5
T				2 (Thinking vehicles; ITS)	2
2012 Total	**1**	**6**		**2**	**9**
2013					
A		1 (Monitor accidents)			1
I		1 (Car model website)			1
2013 Total		**2**			**2**

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Table 7 - Volvo's IS-enabled Sustainability Initiatives Data					
Year	**Q1**	**Q2**	**Q3**	**Q4**	**Grand Total**
2014					
A	2 (VSIB-Volvo Supplier Information Database; Machine off)	2 (ADAS-Advanced Driver Assistance Systems; AEBS-Auto breaking systems)			4
I		2 (surrounding scanning and actions suggestions; Real-time driver feedback)			2
T				2 (I-See; Power lines in road)	2
2014 Total	**2**	**4**		**2**	**8**
2015					
I		2 (Financials; CareTrack-Remote vehicle diagnostics)			2
2015 Total		**2**			**2**
Aggregate					
A	5	5			10
I	2	13			15
T				4	4
Grand Total	**7**	**18**	**0**	**4**	**29**

Table 8 - Caterpillar's IS-enabled Sustainability Initiatives Data					
Year	**Q1**	**Q2**	**Q3**	**Q4**	**Grand Total**
2010					
A	3 (Autopaint; energy savings)	1 (Accugrade)			4
I		1(PLS-Product Link Systems)			1
2010 Total	**3**	**2**			**5**
2011					
A		2 (Auto-shift)			2
I		1 (CAT Minestar)			1
T		1 (AMT-Autonomous Mining Truck)			1
2011 Total		**4**			**4**
2012					
A	3 (Simulations; energy savings)				3
I		3 (PA; CAES; CC)			3
2012 Total	**3**	**3**			**6**
2013					
I	1 (CLMS)	1 (Driver attention)			2
2013 Total	**1**	**1**			**2**
2014					
A		2 (Compaction; Eye tracking)			2
2014 Total		**2**			**2**
2015					
A	1(Energy savings)				1
I		3 (NKS; Microgrid solar systems; Driver-tracking)			3
T			1(OOMD-One Operator to control Multiple Dozer)	1(AMS-Autonomous Mining Systems)	2
2015 Total	**1**	**3**	**1**	**1**	**6**
Aggregate					
A	7	5			12
I	1	9			10
T		1	1	1	3
Grand Total	**8**	**15**	**1**	**1**	**25**

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Volvo and Caterpillar mostly implemented IS-enabled sustainability initiatives for today's quadrants (Q1 and Q2). Interestingly, both companies implemented twice as many initiatives for Q2 than for Q1, and none implemented any infrastructure initiative during the studied period. This could be attributed to the emergence of technologies such as self-driving, distance diagnostics, etc. that can improve product quality and safety. Both companies relied more heavily on automate initiatives for Q1 and more heavily on informate initiatives for Q2.

Volvo implemented multiple automate initiatives for Q1. For example, in 2010, it implemented a system that supported selecting safer chemicals and avoiding banned ones (A, Q1). Also in 2010 it automated a database for handling customer feedback (A, Q1). In 2011 it also created a system to support meeting international rules on dangerous materials (A, Q1).

For Q2, Volvo relied more on informate initiatives (9 out of 15 Q2 initiatives). In 2010, it launched a crowdsourcing app to generate ideas for cleaner commutes and also a CareTrack Telematics system that transmits machine data over the internet (I, Q2). In 2011, it created an E-learning for purchasers (I, Q2). In 2012, it created a system to evaluate vendors and a fleet management software for monitoring vehicle data (I, Q2). By 2014, it implemented systems that provide drivers with surrounding environment scanning and immediate sustainability data (I, Q2). *Volvo's qualitative data supports Hypotheses 1, 2.*

For Q4, Volvo had several transform initiatives. In 2012, it began developing an Intelligent Transport System and also machines that work without operators (T, Q4). In 2014, the company tested a system for roads to charge electric buses and a system called I-See where route information is saved for future driving fuel optimization (T, Q4). *Volvo's practice deviates from hypothesis 4's logic by using four transform initiatives for quadrant 4.*

Caterpillar also implemented multiple automate initiatives for Q1. In 2010 and 2011, Caterpillar implemented automate initiatives to improve efficiency in painting autos and managing lighting (A, Q1). In 2012 and 2015, it continued to use automate initiatives to reduce energy use and improve safety (A, Q1).

Among 15 initiatives in Q2, Caterpillar implemented 9 informate initiatives. These included the ability to monitor trucks remotely, avoid collisions with proximity awareness and to provide immediate feedback to operators and supervisors. In 2013, it created a system to track drivers' attention and log the information (I, Q2). In 2015, it created a microgrid solar energy system for customers (I, Q2). *Caterpillar's data supports Hypotheses 1, 2, and 3.* Similar to the first four case companies, Volvo and Caterpillar implemented IS-enabled initiatives to address both environmental and social sustainability.

We also recorded several transform initiatives for Caterpillar. In 2011, it created an autonomous mining truck fleet (T, Q2). In 2015, it started to develop a system where one operator could control multiple dozers simultaneously (T, Q4) as well as an autonomous mining system for everything from fleet assignment and condition monitoring to remote and autonomous control. (T, Q3). We hypothesized that transform initiatives would mostly occur in Q3 but in Caterpillar's case we found them in Q2 and Q4 as well.

Discussion

Examining six leading sustainable global companies across three industries with differing levels of IS intensity, the Friedman test results as well as individual cases' qualitative data largely support our hypotheses. It is also notable that the initiatives observed addressed not only environmental but also social sustainability issues, focusing on both internal and external stakeholders.

Across the cases, the majority of initiatives focus on addressing today quadrants (58 Q1 and 64 Q2 initiatives, out of 145 total initiatives). Five case companies were also individually observed to mostly focus on Q1 and Q2 initiatives. The only exception is Biogen, which had about the same today quadrants (Q1 and Q2) initiatives as tomorrow quadrants (Q3 and Q4) initiatives. Biogen's tomorrow quadrants initiatives were observed during later years of the studied period, after Biogen decided in 2013 to move IS and analytics directly into research and drug development. Biogen appears to be seizing the opportunity to use sustainability as a competitive weapon for the future.

Friedman tests support our hypotheses for automate, informate, and transform initiatives. Meanwhile, we observed support for infrastructure initiatives for hypothesis 1 (Q1), but did not observe support for Infra initiatives for hypotheses 2 and 3 (for Q2 and Q3). Two possibilities explain the lack of observed support. First, most infrastructure initiatives we observed were Q1 infrastructure optimization initiatives (Green IT initiatives), providing support for hypothesis 1. Meanwhile, hypothesis 2 argues for infrastructure integration with supply chain partners to enable co-operation for sustainability. However, most of Q2 initiatives observed dealt with interaction with individual external stakeholders (e.g. customers) rather than supply chain partners. Therefore, it was understandable that companies did not implement infrastructure integration initiatives. Given very few Q3 initiatives were observed (7/145), it is understandable that companies did not implement infrastructure flexibility initiatives.

Additionally, the Friedman test for hypothesis 4 is not statistically significant. This could be explained by the very small number of Q4 initiatives observed in the data set (16/145). However, it is interesting to note that companies implemented seven transform initiatives, besides nine informate initiatives, in Q4. Perhaps this could help us in reexamining the theoretical development of the ISF to include transform initiatives in the hypothesis 4 logics. Our research has implications for both research and practice.

Contributions to IS and Sustainability Literature

Our research contributes to the literature and has implications for future research on IS and sustainability in multiple ways. First, as discussed above, the IS literature so far lacks more thorough overarching theoretical understanding that has also been empirically examined on how IS enables companies to develop capabilities to address sustainability. Using the RBV and ISF as theoretical foundation, together with a mixed-method approach of combining multiple-case study and non-parametric statistical analyses, our research provides initial empirical quantitative and qualitative support for an overarching theoretical model relating information systems with sustainability. Our findings highlight the importance that IS play in enabling companies to become more sustainable, both environmentally and socially, and remain competitive. Additionally, we help open the IS box to show that different types of IS-enabled sustainability initiatives – automate, informate, transform, infrastructure – play distinct roles in in helping firms develop sustainability capabilities for different sustainability objectives across the four quadrants of the ISF.

Besides our theoretical arguments, our quantitative and qualitative data provide insights on particular IS-enabled sustainability initiatives that leading sustainable companies deploy within different quadrants of the ISF, and how such leading companies' sustainability strategy and actions progress within the ISF. Such insights support our theoretical arguments that companies should deploy IS-enabled initiatives to also address the social dimension of sustainability, contributing to our IS literature that has so far mostly focused on environmental sustainability dimension.

Lastly, our theoretical sampling approach and use of seven years of sustainability reports provide both qualitative details and quantitative comparisons. The GRI database and our

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methodology allows researchers to gather IS-enabled sustainability data across a global cross-section of companies, industries and time frames.

Implications for Future Research

Besides its contributions to the current literature, our research also has implications for future research on IS and sustainability. First, our research highlights the importance of studying the integration of IS and business resources, via IS-enabled sustainability initiatives, to help companies deliver sustainability value to stakeholders and concurrently maintain sustained competitive advantage for themselves. Therefore, scholars studying IS and sustainability should pay attention to such integration in future research. Particularly, inter-disciplinary research is encouraged to examine such integration. We also encourage business scholars in general to incorporate more prominently the role of IS resources in helping firms address sustainability.

Second, we also recommend moving beyond "Green IS" to "Sustainable IS" to study the role of IS in helping companies address both environmental and social sustainability issues. We hope that future research will develop further theoretical models and deploy multiple empirical approaches in providing further in-depth knowledge as well as more thorough theoretical understanding of how IS could help companies succeed in addressing all three dimensions of the TBL.

Thirdly, we encourage future research to use GRI reports as an excellent secondary data source for examining sustainability strategy, particularly IS sustainability strategy and IS-enabled sustainability initiatives. We also hope future research will establish new methods for enlarging the scope of data so that more rigorous parametric statistical analyses can be carried out.

Implication for Management Practice

While ISF is an established theoretical framework, our empirical support of the framework proves that it is a useful framework to guide IT/IS and business managers and executives in how to invest in information systems to support their sustainability strategy. In doing so, it is important that these managers and executives take into consideration the distinct contributions of different types of IS-enabled initiatives in driving sustainability.

Secondly, our findings show that over the last decade, companies have increasingly engaged in social sustainability, and IS has played an increasingly integral role in that endeavor. Therefore, it is recommended that companies embrace sustainability holistically, addressing both environmental and social sustainability. It is also important that IT/IS and business managers work closely to integrate complementary IS and business resources to deploy well planned IS-enabled business initiatives in support of their sustainability strategy.

Conclusion

Using a series of cases and non-parametric statistical analysis, our study has provided empirical support for our hypotheses on how different types of IS-enabled sustainability initiatives are used by companies to address both environmental and social sustainability across the four quadrants of the ISF. We hope that our research has provided a significant contribution to our collective understanding of the role of IS in enabling companies to address sustainability. We also hope that our research has provided further support to encourage IS and business scholars and practitioners to embrace the integral role of IT/IS in enabling companies to address sustainability holistically, paying attention to all three aspects of the TBL, leading to a more sustainable world and business market.

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Appendix

CODING RULES

Initiative Type Coding:

- *Automate Initiative:* IS-enabled initiatives that help firms automate business processes, reducing or eliminating the hands-on role served by human resources in order to carry out work processes and work tasks faster, more efficiently and/or more accurately.
  Examples:
  - Automated workforce statistics data management system.
  - Database and automated data entry systems at distribution sites.

- *Informate:* IS-enabled initiatives that make available new, timely, more complete and relevant data to managers, employees and external entities (e.g., customers and suppliers) to enable them better understand the work situations being faced to make better and faster decisions and carry out work processes and work tasks more effectively and/or more efficiently.
  Examples:
  - Web portals to provide and collect sustainability standards/information to/from employees, suppliers, or customers.
  - Company-wide carbon accounting systems for core operation' and value chain's carbon footprint.

- *Transform:* IS-enabled initiatives that help firms restructure or reconstitute business assets, capabilities, practices, processes and/or relationships that would fundamentally alter existing business processes and/or models that enable an organization to create new products/services that position firms more favorably in the product-markets.
  Examples:
  - Providing patients with wearables and personalized medicine.
  - Automated vehicle fleet where one operator could control multiple dozers simultaneously.

- *Infrastructure:* Initiatives that include both technical and human resources such as servers, networks, user devices, shared databases, help desk, etc. that provide platforms through which standardized technical services are provisioned and based on.
  Examples:
  - Standardizing and simplifying IT systems used for quality and compliance.
  - Green data center, cloud based and right sized servers.

Quadrant Coding:

- Quadrant 1: Initiatives addressing current internal sustainability performance.
  Examples:
  - IS-enabled initiatives such as energy or safety monitors for internal use.
  - IS-enabled initiatives to help select safer chemicals and avoid banned ones.

- Quadrant 2: Initiatives addressing current external sustainability performance (e.g. whole supply chain's sustainability performance).
  Examples:
  - IS-enabled initiatives such as websites/apps for use by external stakeholders (suppliers and customers) for sustainability improvement.

- Quadrant 3: Initiatives addressing future internal sustainability performance.
  Examples:
  - IS-enabled initiatives such as data mining for internal new products development or reorganizing IT department to help spur Research & Development.

- Quadrant 4: Initiatives addressing future external sustainability performance.
  Examples:
  - IS-enabled initiatives such as wearable devices for underserved patients or self-driving trucks.

Additional Coding Rules

- Code at the level of the paragraph, the appropriate code is the highest level (infrastructure, automate, informate, transform) usage of IT/IS indicated in the paragraph.
- Code for highest role and stage (Infra-A-I-T and Q1-4) when enough information available. Lowest when not enough information.
- If there is not enough detail to determine the nature of the business IS-enablement involved (such a discussion could be based on altering a manual system), no code is assigned. If there is enough detail to determine that business IS-enablement is involved but not enough to distinguish automate, informate or transform, assign a code of automate.
- Code multiple instances of the same issue but only if each instance includes enough detail about the IT/IS issue to assign a code (in other words, do not assign a code based on information provided in other paragraphs).
- Code for information about information technology that is embedded in industrial technology with enough detail.
- Same initiative mentioned across multiple years: Only code for first year that it is mentioned.

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