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How to Enhance and Ensure Green Information Systems Capability for Green Performance? An Operant Resources Perspective

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Completed Research Paper

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Abstract

Under the growing environmental pressure and concern, organizations invest in information technologies for analytics and decision support in environmental sustainability management. Specifically, organizations should ensure the proper utilization of green information systems (IS) to achieve appropriate environmental outcomes. Otherwise, green IS becomes a non-performing asset, making it a low priority in organizations' sustainability plans and strategies. This study anchors to the operant resources hierarchy perspectives and investigates how green IS relevant capabilities build on each other for environmental performance. With a matched dataset of 73 organizations from multiple sources, this study tests the effects of green support and information assurance on the relationship between green IS capability and green performance. The findings indicate that as composite operant resources and interconnected operant resources, the interactions of green support, information assurance, and green IS capability can improve organizations' green performance.

Keywords: Green IS, carbon emission, operant resources, green support, information assurance

Introduction

Information technology (IT) can help to mitigate sustainability-related challenges. With the advancement of IT, there are more and more ways to leverage IT for sustainability. IT has permeated various business processes and impacted firms with beneficial implications for business models, firm strategies, and performance (Bharadwaj et al., 2013; Sambamurthy et al., 2003). Early literature focused more on the direct impact of IT on the environment, such as energy use and greenhouse gas emissions in data centers (Jenkin et al., 2011). Later, studies explored IT/IS's enabling and systematic effects in various areas at multiple levels. Accordingly, there are different opinions on two terms: green IT and green IS.

On the one hand, green IT focuses more on IT artifacts, tools, applications, and implementations and how to reduce the negative impacts of IT on the environment. On the other hand, green IS focused more on systems and their subsequent broader scope, referring to how IS contributes to environmental sustainability. In this paper, we highlight the IT-based or IT-enabled nature of green IS to understand this term from a new perspective.

Green IS are not simply limited to the tools or artifacts but IT-enabled affordances and functionality for environmental sustainability (Melville et al., 2017). This conceptualization is aligned with the resource-based view (RBV) that is used to explain the relationship between IT and the competitive advantage of a firm and IT capability and firm performance (Bharadwaj, 2000). However, how resource-based aspects of information systems create value through complementarity and assurance of capabilities remain less explored. The motivation of this study is to address this research gap. This study theorizes green IS capabilities as operant resources, and to gain value from green IS, organizations need to deploy green IS effectively to integrate and leverage different levels of resources toward performance development. More specifically, the performance investigated in this study is of environmental rather than economic value.

Arguments and hypotheses are presented from the hierarchy of operant resources perspectives. First, by analyzing the green IS currently on the market and applied in firms, this study looks closely at the green IS capabilities in specific scenarios: carbon, waste recycling, energy, and compliance. Second, one common observation from the prior literature is the importance of top management support in achieving environmental sustainability (e.g., Huang et al., 2020; Rahim and Rahman, 2013). Therefore, this study considers the composite effects of top management support and green IS capability on environmental sustainability (i.e., green support). Finally, from the interconnected operant resources perspective, we investigate the resources reinforcing green IS capability and IS assurance. This study focuses on green performance, i.e., environmental sustainability, more specifically, the carbon emission performance of an organization. Prior research suggested that environmental metrics, such as CO_2 equivalent, can be used to evaluate the impact of green IS on environmental performance (Melville, 2010).

We collected data from multiple sources and analyzed data using econometric models to test the hypotheses empirically. Additional analysis is conducted to test the estimation robustness and to get a more nuanced understanding of the estimations. The key findings of this research are: (1) with more green IS capabilities, organizations can gain better green performance, (2) along with the green IS capability, the presence of top management green support can enhance organizations' green performance; and (3) the interaction between green IS capability and information assurance can improve organizations' green performance.

This study contributes to the literature on green IS and operant resource perspectives. It offers a fresh perspective on green IS research by using operant resources perspectives to understand the mechanism of green IS to improve organizations' environmental sustainability. It also complements extant research by applying the theory of composite and interconnected operant resources to the IS area. By analyzing the green IS currently being used by organizations, this empirical study also provides practical implications for organizations to achieve better green performance with green IS investment.

Hierarchy of Operant Resources and Three Levels of Green IS Capability

Constantin and Lusch (1994) proposed the concept of operant resources as resources that produce impacts and outcomes on other resources. Madhavaram and Hunt (2008) proposed a hierarchy of operant resources, which has three levels: basic operant resources, composite operant resources, and interconnected operant resources (see Figure 1).

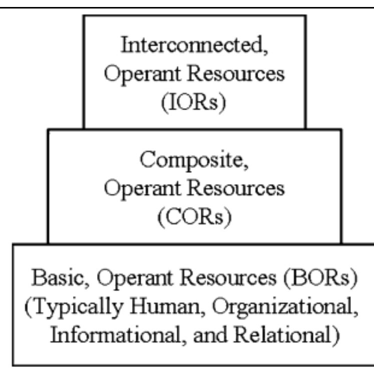

Figure 1. Hierarchy of Operant Resources (Madhavaram and Hunt, 2008)

Basic Operant Resources are "the underlying, lower-level resources that form the building blocks of higher-order, operant resources." Composite Operant Resources are "a combination of two or more distinct, basic resources, with low levels of interactivity that collectively enable the firm to produce efficiently and/or effectively valued market offerings." Interconnected Operant Resources are "a combination of two or more distinct, basic resources in which the lower order resources significantly interact, thereby reinforcing each other in enabling the firm to produce efficiently and/or effectively valued market offerings." The hierarchy proposed by Madhavaram and Hunt (2008) provides a new way to examine the orchestration of operant resources. This operant resource hierarchy has been used as an established theoretical lens in supply chain-related research (e.g., Chandler and Vargo, 2011) and other areas. In the IS domain, very little research has employed this hierarchy. In a study on cloud computing by Kathuria et al. (2018), the authors draw on the perspective of operant resources hierarchy to examine cloud operant resource development. Furthermore, no studies have conceptualized green IS from the operant resource conceptual viewpoints.

Extant research has mainly focused on establishing the value of green IS, dealing with it as a standalone concept. The concept of complementarity with other resources and assurance of the capabilities to create value remains a sparse area of investigation. We articulate this complementarity and assurance aspect using a broad three-level process that can improve the performance effects of green IS (see Table 1).

In the multi-level conceptualization, the first level is the green IS capability, including green IS functionalities. For general technology, mostly, it is considered as material artifacts (Orlikowski, 1992). In the IS domain, researchers distinguish IT as IT capabilities and IT assets. IT capabilities were viewed as competencies and practices (Aral and Weill, 2007) or IT investment and IT management practices (Benitez-Amado and Walczuch, 2012). More specifically, for enterprise information systems, researchers considered the physical scope, such as value chain modules and enterprise support modules, as IS capabilities, whereas the functional scope, such as HR and finance, as IS resources (Ranganathan and Brown, 2006; Rush et al., 2015). Researchers also suggested Enterprise Resource Planning (ERP) functional scope as a component of ERP capabilities (Karimi et al., 2007). Green IS has a broad functional area at the three managerial decision levels, including engineering and design, procurement, manufacturing and production, sales and marketing, logistics, finance, accounting, and human resources (Sarkis et al., 2013). The realm of green IS functionalities has extended from the early common conception of "information technology tools and technologies" aspects only to include the views of the system involving the organization. For example, recent studies have considered information to support decision-making, direct IT assets and infrastructure, sustainable products and services, collaboration, and similar organization-wide intangible aspects (Corbett, 2013; Nishant et al., 2017). Except for the "direct IT assets and infrastructure" belonging to green IT, the other three groups are all about IT-enabled functions and capabilities for sustainability. For example, a greenhouse gas monitoring system needs to be embedded in a chimney or furnace at an appropriate place to monitor the emission. However, just having the monitoring device is not enough. It should be installed, connected to a computer, benchmarked, and take action to have adequate emission controls for a green impact. The latter is a decision support mechanism that acts as a monitoring tool to influence performance.

Besides the decision-making support systems, collaboration systems, and sustainable products and services, some other green IS include knowledge management systems for pollution prevention and remediation and decision support systems that systemize cost-benefit analyses and improve environmental risk management (Melville, 2010). These information systems can collect and analyze energy datasets from sensors, technology-enabled data, and knowledge repositories in the environment (Watson et al., 2010; Elliot, 2011). IT-based systems can manage environmental compliance and related organizational risks, support sense and decision-making, and create knowledge about environmental sustainability (Butler, 2011). Prior research notes that some of these may extend to generic and customizable organization-wide systems, with different capabilities involving data storage, validation, analytics, and reporting that help decision-making (Melville et al., 2017).

Although the scope of green IS extends beyond tools and applications to systems approaches, a lack of integration with other existing systems may lead to challenges, which are illustrated in Table 1 as the second-level integration process. As explored in existing research, this integration follows a hierarchical approach, that a composite of two or more distinct operant resources can collectively increase the efficiency and effectiveness of an organization (Madhavaram and Hunt, 2008). The linkage would be the alignment and complementarity of green IS capability and other organizational factors. For example, managers' attitude toward green IS and considering future consequences can influence its implementation for environmental performance, such as pollution prevention (Gholami et al., 2013). From the operant resources perspective, complementarity occurs when operant resources produce more value in the presence of another resource (Karimi et al., 2013). Management support is considered a resource that should come along with organizations' green IS capabilities (Beitelspacher et al., 2012). Effective green IS governance that allocates IS decision rights to align with strategic objectives also indicates that management support can decide the outcome of using green IS (Sarkis et al., 2013).

	Level 1: Green IS Capability	*Level 2: Green IS Capability Complementarity*	*Level 3: Green IS Capability Assurance*
Goals	Have functionality of green IS	Enhance the functionality of green IS	Ensure the functionality of green IS
Focus	Technological competence of green IS	Additional resources to increase green IS capability	Feedback to improve green IS capability

Table 1. Three Levels of Green IS Capabilities

The third aspect of the green IS to performance is the effectiveness of green IS, which measures the system's quality and can fulfill the system's functions (Hamilton and Chervany, 1981). One approach to achieving IS effectiveness is quality assurance which is nothing but an "Independent professional service that improves the quality of information" (Dube and Gulati, 2005). Therefore, usually, the assurance service is provided by a third party. A critical component of information assurance is integrity, meaning a system should ensure the completeness and accuracy of the information (Cherdantseva and Hilton, 2013). According to the hierarchy of operant resources perspective, the interconnected operant resources, i.e., two or more operant resources interacting and reinforcing each other, enable an organization's effectiveness and efficiency (Madhavaram and Hunt, 2008). As the interaction between green IS capability and IS assurance, green IS capability assurance can further improve green IS capability and ensure the functionality of green IS.

Green IS are enablers for companies to reduce environmental impacts. This study will look at the green IS capability, green support, and green information assurance based on the basic, composite, and interconnected orchestration of operant resources. Table 2 presents the conceptualization, characteristics, and outcomes of each level.

Hierarchy	Conceptualization	Characteristics	Outcomes
Green IS Capability (Basic)	Using IT/IS to improve environmental sustainability (green performance)	Can be acquired through the use of IT/IS	Green performance
Green Support (Composite)	Support for environmental sustainability management	Green IS can create greater value with its presence	Increased green performance
Green Information Assurance (Interconnected)	Independent professional assurance services that improve the quality of information from green IS	Interact and reinforce green IS capability	Increased green performance

Table 2. A Hierarchy of Operant Resources for Green Performance

Hypotheses Development

This study defines the green IS capability as the IT-enabled organizational capability to achieve environmental sustainability from the operant resources perspective. Following the prior literature (Rush et al., 2015), this study uses the specific environmental focus of green IS as a proxy for green IS capability. Green support is defined as top management support in environmental sustainability management (Huang et al., 2020). Information assurance refers to the third-party assurance of environmental sustainability-related information (Dube and Gulati, 2005). Instead of financial performance, this study focuses on green performance, defined as the carbon emission generated by an organization (Melville, 2010). This study proposes three hypotheses anchoring to the operant resources hierarchy. The first hypothesis looks at the direct relationship between green IS capability and green performance considering green IS capability as one basic operant resources perspective. The second hypothesis examines the impacts of green IS capability on green performance and the presence of green support from the composite operant resources perspective. The third hypothesis investigates the interaction of green IS capability and information assurance and its influence on green performance. The research model for this study is shown in Figure 2.

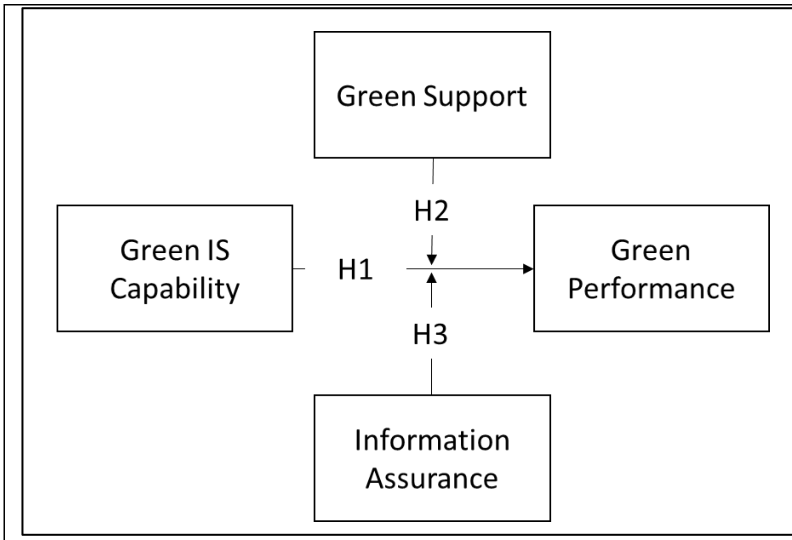

Figure 2. Research Model

Following the operant resources perspective, we view the use of green IS as a means by which organizations can develop environmental sustainability management capabilities that enable them to collect, manage, and analyze environmental data and information, including carbon footprint, waste recycling, energy consumption, compliance and risk (Howard et al., 2014). First, green IS capability enables an organization to use IT to improve its environmental sensing, resource seizing, and reconfiguring abilities (Amaranti et al., 2019). It automates acquiring and assimilating environmental data and information (Cooper and Molla, 2012). For example, green IS can reduce or even eliminate manual environmental data entry and validation. Cross-functional cooperation for environmental improvements becomes easier (Benitez-Amado and Walczuch, 2012). For instance, with the unified green IS platform, different units of an organization can record and submit environmental data and information quickly. Through such automation and coordination, organizations can track their business workflows at a single location and understand how to standardize processes and workflows, reduce waste and consumption, and attain environmental compliance. As a result, the organization can align its processes, people, and products to improve green performance.

Second, the physical implementation scope of green IS determines the level of green IS capability (Rush et al., 2015). In other words, the more environmental concentrations the deployment of Green IS has, the higher green IS capability an organization can represent. The environmental focus regarding carbon emission includes carbon, energy, waste, compliance, and sub-components of green IS (Molla et al., 2009). A waste recycling-focused green IS can only reduce carbon emissions through materials management. An energy consumption-focused green IS only cares about the automation control and management of PC power; a compliance-focused green IS only delivers intelligent compliance solutions; a carbon-focused Green IS is only about carbon measurement.

In contrast to each green IS that has a single environmental focus, a comprehensive green IS reflects higher green IS capability, and it can lead to more reduction in carbon emission due to increased capital and greater synergy (Chuang and Huang, 2018; Nevo and Wade, 2010). A comprehensive green IS can collect and consolidate all types of environmental data to provide a complete picture and allow for a holistic solution to significantly reduce carbon emissions (Giljum et al., 2011). In addition, if more comprehensive green IS are applied, an organization can consolidate the unique features of different green IS to build even stronger green IS capability, thus reducing carbon emissions.

Third, building a higher level of green IS capabilities reflects an organization's time, investment, and commitment to spending on environmental sustainability matters (Madhavaram and Hunt, 2008). Achieving good green performance without such commitments is difficult or even impossible. Prior literature has shown a positive association between sustainability commitment and carbon emission reduction (Rush et al., 2015). This suggests that organizations can improve their environmentally sustainable performance with a higher level of green IS capability. Therefore:

Hypothesis 1: There is a positive association between green IS capability and green performance.

Composite operant resources highlight the complementarity of resources, which indicates that one resource can produce more excellent value in the presence of another (Karimi et al., 2013). In this study, we focus on the composition of green IS capability and green support, which indicates the level of support from top management regarding environmental sustainability (Huang et al., 2020). Given the importance of green IS capability, we argue it is necessary for green performance. However, to achieve outstanding green performance, green IS capability is insufficient; top management support of environmental sustainability is likely to enhance the green performance of an organization.

Prior literature has shown the importance of top management support as a driver of better outcomes in product development (Wren et al., 2000), project success (Young and Jordan, 2008), customer relations (King and Burgess, 2008), and supply chain management (Zhu et al., 2008). With green support from top management, the organization can have a clear vision to plan and direct the use of Green IS capability. Environmental management will not succeed if top management's green support is missing. This type of support is a critical operant resource for organizations as management operates financial and personnel resources for efficient and effective use of green IS capabilities (Thong et al., 1996). Such support also has a critical role in the promotion of new values. The more top management supports the goals of value-creation processes focused on environmental sustainability, the more successful the green performance is (Huang et al., 2020; Rahim and Rahman, 2013). Top management support for environmental sustainability indicates to what extent the top managers demonstrate a commitment to drive the environmental strategy (Banerjee et al., 2003). In other words, with the green support signal shared through the organizational routine, the overall business workflows in an organization can receive that message and react accordingly.

In addition, from the organizational culture perspective, both awareness and practices of environmental sustainability are essential to motivate employees' utilization of green IS capabilities through their skills and knowledge (Beitelspacher et al., 2012), and such organizational cultures can be reinforced by top management support (Daily and Huang, 2001). Strong green support from the top management results in more communications about the importance of green IS. These communications can improve green IS deployment at the firm level and promote green IS-facilitated carbon emission reduction (Graves et al., 2019). Top management support is critical in utilizing these operant resources, such as green IS capability. The stronger the role of top management for environmental sustainability is, the more likely these resources will be utilized appropriately. To summarize, the importance of green support from top management cannot be underestimated, thus:

Hypothesis 2: The relationship between green IS capability and green performance is improved with the presence of green support.

Interconnected operant resources consist of complex combinations of a firm's operant resources, requiring some form of synergistic or interactive effects (Adams et al., 2014) or the orchestration of operant resources (Teece, 2014). This study focuses on the orchestration of green IS capability and information assurance, which refers to the independent assurance service provided by a third party to ensure the completeness and accuracy of environmental sustainability-related information (Dube and Gulati, 2005; Cherdantseva and Hilton, 2013). To achieve the goal of green IS, i.e., environmental sustainability or improved green performance of organizations, we need to ensure the effectiveness of green IS; especially in terms of technological resources in the system-resource view, is indicated by the system quality, and thus quality assurance is needed (Hamilton and Chervany, 1981).

The American Institute of Certified Public Accountants (AICPA) suggests that IS assurance be conducted by independent professional service providers to improve information quality (Dube and Gulati, 2005). It underscores the importance of independent service providers as they can provide unbiased assurance. There are several reasons organizations might provide biased green IS information, such as energy consumption or carbon emissions. There are different methods and standards to calculate carbon emissions, and the party may use the unit that will benefit itself when it sets up the parameters in the system (Gao et al., 2014). Also, the party may provide biased information to understand better the organizational commitment to sustainable practices (Dube and Gulati, 2005). This could either give wrong input to top management's decision-making internally or send misleading signals and images to the public, harming the organization's long-term development (Marquis et al., 2016). Green IS capability cannot improve an organization's green performance with such misuse of IT/IS. Green IS can only function more reliably to provide unbiased information and to achieve actual green performance when independent information assurance is used.

One benefit of green IS is process automation. However, automated systems are not always reliable. There may be errors in the information generated by green IS automatically, such as incomplete and inaccurate information. Humans must engage in error detection and correction as a part of information assurance (McBride et al., 2014). Green IS capability can be improved, and such interaction and reinforcement can improve green performance with feedback from information assurance.

Furthermore, previous literature on sustainability reports has recognized the positive impact of implementing proper control mechanisms for monitoring and improving data measurement systems through the independent assurance of the quality of sustainability information (Briem and Wald, 2018). Researchers also revealed that third-party assurance could provide guidance and feedback on developing efficient internal systems (Park and Brorson, 2005). Similarly, we argue that information assurance can also increase the quality and effectiveness of green IS, leading to a better outcome of achieving environmental sustainability. Thus, we hypothesize that:

Hypothesis 3: The relationship between green IS capability and green performance is improved with information assurance.

Research Methodology

This study uses a matched dataset from multiple data sources to empirically test the hypotheses. A cross-sectional ordinary least square (OLS) regression model is applied for the estimation.

Data

The population for this study is North American organizations that use IS for sustainability. Secondary data were collected from multiple sources, and a matched dataset was used to test the hypotheses. First, the green IS data were collected from the Computer Intelligence (CI) Technology database. This database is a source that provides insight into the installed IT of organizations. It contains company profile information and "annual spending/expenditure on information technology and telecommunications, and counts on installed technology including computer hardware, software, networks, storage and telecommunications, information technology staff/employee counts." The database covers 150,000 North American companies, 80% from the United States and the remaining 20% from Canada. We searched for the keyword GEPRG (i.e., green program), and the result showed that 1,345 organizations (local level) were using green IS in 2017. In addition, we collected enterprise-level data, such as IT employees and IT budgets, on hardware, software, and service from this database.

Second, green support, information assurance, and green performance data were collected from the CDP (carbon disclosure project) database. CDP is a non-profit initiative that conducted an annual survey on firms' carbon emission-related risks and strategies since 2003 (Matisoff et al., 2013). The survey includes four main parts: climate change-related risks and opportunities, emission calculation and verification, performance, and governance (Guenther et al., 2016). Furthermore, the amount of carbon emissions is directly requested, including the different scope and total emissions. The data used in this study are drawn from the surveys conducted in 2017 (green support and information assurance) and 2018 (carbon emission).

Third, Compustat is a widely used database that contains financial information about global companies. This study extracts relevant financial information, such as firm size and industry of the sample firms, to control other factors that may influence green performance.

Variables

The dependent variable of this study is green performance, which is measured by the negative value of the amount of carbon emissions (CO_2 equivalent) in scopes 1 and 2. Scope 1 covers direct emissions from owned or controlled sources, while scope 2 covers indirect emissions from the generation of purchased electricity, steam, heating, and cooling consumed by the reporting company.

There are three independent variables: green IS capability, green support (i.e., top management support for environmental sustainability), and information assurance. According to the CI Technology database, companies use 12 different types of systems to manage environmental sustainability (see Table 3). Some systems are comprehensive, while others only have one environmental focus (e.g., carbon, waste recycling, energy, compliance). Regarding the application, some companies use only one type, while others use multiple (up to five) systems. Following prior literature (Rush et al., 2015), this study calculates the total weight of green IS based on its environmental focus (overall=1, partial=0.25). This total weight is used as the proxy to measure an organization's green IS capability.

	Green IS	**Description**	**Environmental-focus**
1	SAP Sustainability	The SAP Sustainability Performance Management deals with the measurement, management, and disclosure of organizational performance toward the goal of sustainable development. The first time we have a solution that allows companies to manage their entire sustainability performance holistically	Overall
2	Enablon	A system that provides companies with an extensive, reliable, and highly popular Sustainability, EHS, and Operational Risk Management Software, cloud-based	Overall
3	SAP Carbon Impact	A carbon measurement solution that connects with an organization's backend SAP systems provides end-to-end measurement and dashboarding capabilities of a business's carbon impact.	Carbon
4	SAP Recycling Administration	The Recycling Administration (REA) component focuses on the item-based or weight-based fee calculation for specific materials, as well as end-to-end transparency and implementation of the legal reporting requirements to environmental authorities.	Waste Recycling
5	ProcessMAP	A cloud-based environmental health safety (EHS) solution that also offers risk and compliance management	Overall
6	3E Company =Verisk 3E	Intelligent compliance solutions empower companies to reduce risk, drive continuous improvement, and create new growth opportunities.	Compliance
7	Medgate =Cority	A web-based/cloud-based software solution fully stacked with features to enhance workplace environmental, safety, and health standards. A comprehensive, modular, and enterprise-grade EHS and Quality Management software.	Overall
8	Enviance	A cloud-based environmental, health, safety, and sustainability (EHS) solution that enables businesses of all sizes to manage and track compliance requirements, employee well-being, emission inventory, and more	Overall
9	Gensuite	Cloud-based software solutions can track their environmental impact, look after the health of their employees and manage the safety status of equipment and other important assets.	Overall
10	Verdiem	Enterprise-class PC Power Management software	Energy
11	SiteHawk	Safety Data Sheets (SDS) and chemical data management solutions; Cloud-based Technology; cloud software and services deliver a complete approach to chemical data management, providing data, intelligence, and reporting to support safety, compliance, and risk management.	Overall

12	Verisae	cloud-based solution that helps large retailers automate their maintenance, energy, field service, and remote monitoring programs	Overall

Table 3. Organizational use of different types of Green IS as per the CI dataset

In the CDP survey, questions such as "Where is the highest level of direct responsibility for climate change within your organization?" were asked to understand the top management's support for environmental sustainability. This study codes the answer to this question to measure the green support variable (1=other manager/officer, 2= senior manager/officer, 3=board or individual from board). The CDP survey also asks to indicate the assurance status of the carbon emissions. This study codes the answer to this question to measure the information assurance variable (1=third party assurance process in place, 0=No third party assurance).

As mentioned earlier, this study considers several control variables. IT/IS employee is measured by the number of IT or IS-related employees in an organization. The percentage of the hardware budget is calculated as the ratio of the hardware budget to the total IT budget; the percentage of the software budget is calculated as the ratio of the software budget to the total IT budget; the percentage of the service budget is calculated as the ratio of service budget to total IT budget. Firm size is measured based on an organization's total number of employees. The SIC code distinguishes the industry of a firm. The variables are listed in Table 4.

Variables	Measurement	Source
Dependent Variable		
Green Performance (GP)	The negative value of the amount of carbon emission (CO2e)	CDP, 2018
Independent Variables		
Green IS Capability (GISC)	The capability to use IS for environmental sustainability. *Coding:* Environmental focus (overall=1, partial=0.25)	CI Tech, 2017
Green Support (GS)	The level of management support to environmental sustainability management. *Coding:* 1=other manager/officer, 2= senior manager/officer, 3=board or individuals from the board	CDP, 2017
Information Assurance (IA)	The involvement of third-party assurance for the carbon emissions information *Coding:* 1=has third party assurance, 0=no third party assurance	
Control Variables		
IT/IS employee (ITE)	The number of IT or IS-related employees	CI Tech, 2017
% of hardware budget (Hard)	The ratio of hardware budget to total IT budget	
% of software budget (Soft)	The ratio of software budget to total IT budget	
% of service budget (Serv)	The ratio of service budget to total IT budget	
Industry (Ind)	Coded based on SIC code	Compustat, 2017
Firm size (Size)	The log of total employee	

Table 4. Variables Table

Results

Table 5 presents the summary statistics and correlations of variables. The average carbon emission is about 7.7 million tons, and the average green IS capability level is 1.3. The average level of green support is 2.7, indicating a high level of green support, and the average value of information assurance is 0.7, indicating many organizations have third-party assurance for their carbon emissions information. For the control variables, the average number of IT/IS employees is 41, the average ratio of hardware budget is 3.3%, the software budget is 0.8%, and the service budget is 7.5%.

	Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9
1	GP	-7.712	16.864	1.000								
2	GISC	1.348	0.796	0.134	1.000							
3	GS	2.683	0.494	-0.137	-0.174	1.000						
4	IA	0.695	0.463	-0.135	-0.322	0.274	1.000					
5	ITE	41	82	0.036	0.101	-0.245	-0.211	1.000				
6	Hard	0.033	0.019	0.097	-0.033	0.007	-0.007	-0.176	1.000			
7	Soft	0.008	0.003	-0.067	0.080	0.015	0.209	-0.018	0.291	1.000		
8	Serv	0.075	0.013	-0.334	-0.001	0.094	0.051	-0.085	0.417	0.446	1.000	
9	Ind	2.692	1.887	-0.118	0.090	-0.225	-0.241	0.303	-0.217	0.085	0.058	1.000
10	Size	4.782	1.551	-0.122	0.081	0.182	-0.079	-0.027	-0.064	-0.247	-0.350	0.011

Table 5. Summary Statistics and Correlations Table

Table 6 shows the main estimation results. First, column 1 of this table presents the direct relationship between the green IS capability and green performance. The result (β=4.116, p<0.1) indicates a significant and positive relationship between the level of green IS capability and organizations' green performance. In other words, organizations can gain better green environmental performance with a higher level of green IS capability. This result supports H1. Second, model 2 in column 2 is about the impacts of green IS capability on green performance with the presence of green support. The results show that the moderating effect is significant and positive (β=3.392, p<0.05). This result is consistent with the argument in Hypotheses 2 and thus supports H2. Third, model 3 in column 3 is about the interaction of green IS capability and information assurance. The result (β=4.444, p<0.1) indicates the significant and positive moderating effect of information assurance on the direct relationship between green IS capability and green performance.

VARIABLES	(1) Green Performance	(2) Green Performance	(3) Green Performance
GreenISCapability (GISC)	**4.116***	3.101	-1.950
	(2.228)	(9.071)	(3.419)
GreenSupport (GS)		2.731	
		(6.873)	
GISC×GS		**3.392****	
		(1.644)	
InfoAssurance (IA)			-21.150**
			(9.876)
GISC×IA			**4.444***
			(2.271)
ITEmployee	0.007	0.006	-0.010
	(0.012)	(0.011)	(0.013)

Hardware	-1.794	-1.862	1.644
	(1.548)	(1.571)	(1.510)
Software	3.855**	3.955**	2.913
	(1.535)	(1.540)	(2.316)
Server	-2.408	-2.593	-3.607**
	(2.360)	(2.386)	(1.384)
Size	-0.581	-0.844	0.743
	(1.010)	(1.077)	(1.038)
Constant	5.613	1.400	5.677
	(13.047)	(20.219)	(15.836)
Observations	73	73	73
R-squared	0.336	0.342	0.388

Table 6. Main Estimation Results

Robust standard errors in parentheses; *** *p<0.01,* ** *p<0.05,* * *p<0.1*;
industry dummies are omitted for brevity.

In addition, prior researchers have found that other factors such as carbon emission goal setting, and climate-related risk perception can affect the carbon emissions of an organization (Melville et al. 2017, Ning et al. 2019). This study also includes business strategy and risk perception as additional control variables to address the potential endogeneity issues. Table 7 shows the analysis results with these additional control variables. The results are largely consistent with the main results in Table 6.

VARIABLES	(1) Green Performance	(2) Green Performance	(3) Green Performance
GreenISCapability	**4.089***	-12.052	-1.884
	(2.275)	(8.723)	(4.468)
GreenSupport		-10.794	
		(7.880)	
GISC×GS		**3.379****	
		(1.682)	
InfoAssurance			-21.733**
			(10.010)
GISC×IA			**4.394***
			(2.621)
RiskPerception	0.210	-0.001	0.964
	(1.142)	(2.037)	(2.030)
BusinessStrategy	-5.230	-1.376	-5.063
	(3.380)	(16.709)	(16.494)
ITEmployee	-0.006	-0.004	-0.006
	(0.012)	(0.022)	(0.022)
Hard	1.773	1.727	1.608
	(1.576)	(1.186)	(1.180)
Soft	2.348	2.181	2.894

	(2.400)	(2.008)	(2.072)
Server	-3.883**	-3.466***	-3.742***
	(1.571)	(1.152)	(1.135)
Size	0.606	0.783	0.745
	(1.037)	(1.370)	(1.361)
Constant	-0.978	13.014	7.811
	(15.519)	(35.209)	(30.154)
Observations	73	73	73
R-squared	0.337	0.385	0.392

Table 7. Additional Analysis Results

Robust standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$; industry dummies are omitted for brevity.

Discussion

Green IS are technologies or systems that organizations use to achieve better environmental sustainability and green performance (Melville, 2010). Studies relevant to strategy and green outcomes of specific green IS from operant resources perspectives are limited. This study highlights the operant nature of green IS capability to address the research gap by anchoring it to the operant resources perspective. We propose the three levels of green IS capability, and we study the hierarchy of operant resources for green performance in the order of basic, composite, and interconnected operant resources. Accordingly, we develop three hypotheses to explain how green IS influences the green performance of organizations. Matched data from multiple sources are used to test these hypotheses, and we find support for our hypotheses from the analysis results. We first found a significant positive relationship between green IS capability and green performance. This finding implies that organizations can gain better environmental sustainability performance with higher green IS capability. Furthermore, we found the positive moderating effects of both green support and information assurance, indicating that with the presence of green support, green IS capability can achieve better green performance. Finally, the interaction of green IS capability and information assurance can also improve organizations' environmental performance.

This study contributes to both theory and practice. It has several theoretical implications. First, prior literature on IT for sustainability focus on the antecedents and consequences of green IS. There is a gap in investigating the underlying link between capability and performance. By examining the framework from green IS capability to green performance, this study contributes to the large stream of literature on IT for sustainability. Second, very few researchers have applied the operant resources perspective in IS research (Kathuria et al., 2018). Drawing on the hierarchy of operant resources, this study proposes the three levels of green IS capability, which can be generalized in future green IS research. The hierarchy view of green IS capability provides a new approach for researchers to understand digital strategies and thus adds to the growing literature in this arena. Third, to explore the operant nature of green IS capability, this study has an extensive discussion on resources and capabilities as well as green capabilities. Thus, this study contributes to the growing literature on IT-enabled capabilities, especially for environmental sustainability.

This study also has important practical implications. First, it demonstrates the positive impacts of green IS capability on green performance. This finding can facilitate the use of green IS in businesses. To achieve better environmental sustainability, organizations must implement more comprehensive green IS with more functionalities. Second, this study suggests the complementarity of green IS and green support from the composite operant resources perspective. Practically, the management team should present more support to the environmental sustainability practices to further leverage the use of green IS. Third, from the interconnected operant resources perspective, this study shows the significance of information assurance on green performance when using green IS. While aiming to use green IS to improve green performance, organizations should employ third-party information assurance services to assure information quality and objectivity.

This study has some limitations that could be addressed in future research. First, this study only uses single-year data of the green IS capability to test the hypotheses. This limits our findings' generalizability. Future research should use multiple years of panel data and large sample size to improve the robustness of the results. Second, the variables in the current study are coded based on secondary data. Even though such a measurement scheme provides adequate insights into the interactions of these variables, future research could include survey data that measures the intensity of green IS capability, green support, and information assurance which may provide additional insights. Finally, although we considered additional control variables in additional analysis, it is plausible that other variables intervene or mediate in the research model examined in this study, which presents an opportunity for future inquiry.

Conclusion

With the growing climate change challenges, efforts to promote environmental sustainability profoundly impact our society. Information technologies have the potential to address environmental sustainability issues. Business organizations use IT to manage their environmental-related activities to achieve environmental objectives. Drawing on the operant resources perspective, this study highlights the role of green IS capabilities (basic, composite, and interconnected) as operant resources in improving environmental performance.

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