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The Role of Green IS Governance: Climate Change Risk Identification and Carbon Disclosure Performance

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Green IS in Sustainability Governance: Climate Change Risk Identification and Carbon Disclosure Performance

Completed Research Paper

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Abstract

Climate change is a global risk. Perception of this risk differs from business to business, influencing the variation in responses. Prior studies suggest that businesses need to prepare and respond to climate risk, while embedded within their institutional settings. Less is known about the role of information systems (IS) in this process. In this study, we explore the role of green IS in sustainability governance to influence firms' carbon disclosure performance. We hypothesize that implementation of green IS and the verification against standards, moderate the effects of climate change risk-intensity perception on the carbon disclosure performance, either positive or negative, depending on the institutional environment in which the firm is situated. We use samples of firms from the United States and Europe to test and validate our hypotheses. The main contribution of this study is proposing and validating institutional variations of the green IS in the sustainability governance framework.

Keywords: climate change risk, green IS, sustainability governance, institutional settings, carbon disclosure performance.

Introduction

Climate change poses different types of risks for firms. These include physical risks, regulatory risks, and other general risks (Engel et al. 2015). The last decade witnessed the change of firms' attitudes towards climate change, from denying climate change regulatory updates to exploring potential risks (and opportunities) caused by climate change (Kolk and Pinkse 2005). Researchers suggest that proper response to climate change-related risks can be beneficial for firms and enhance their competitive advantage. As greenhouse gas (GHG) emission is considered as the main reason for the human-made climate change, managing carbon emission is one of the imminent sustainability strategies that firms can select to respond the climate change risks (Hoffman 2005).

A firm's sustainability governance should include economic progress, social development, and environmental improvement tenets (Kolk 2008). Governance that includes environmental improvement fosters sustainability and helps companies to create value. Along with, companies also realize long-term benefits, including reducing risks, attracting new investors and shareholders, and increasing the company's

equity. Firm's board and senior managers rely on governance to guide and help them to manage the company, develop control mechanisms, increase shareholder value, and promote satisfaction with shareholders and stakeholders (Guenther et al. 2016). Sustainability governance is often responsive to the context in which a firm is situated. Institutional environment, consisting of the beliefs, regulations, and policies, influence the firm-level sustainability governance (Diebecker and Sommer 2017). Thus, while sustainability governance is considered as processes that realize the value creation for stakeholders through accommodation of environmental concerns, institutional differences that exist globally may influence this process.

Information technologies (IT) help and manage the monitoring and reporting of sustainability indicators. Research on the use of IT for sustainability is mostly discussed with the green information systems (green IS) lens and is proposed to be beneficial for carbon emission management and governance (Melville 2010). In this regards, studies have suggested relevant importance and premise of the sustainability systems approach (Corbett 2013; Melville 2010; Seidel et al. 2013) and have discussed the role of initiatives and processes of the systems in improving firms' environmental and financial performance (Khuntia et al. 2017; Shrivastava 1995). Studies have alluded that organizational and managerial factors such as structure, process, and people orient a firm towards sustainability (Alreemy et al. 2016); and some suggest that verification against standards for management quality control and quality assurance of the green IS implementation should be followed as a sustainability governance process (Melville and Whisnant 2014). However, existing literature does not specifically explicate the role of green IS in sustainability governance, nor has provided elements of such governance process that can help firms for better sustainability disclosure.

Institutional embeddedness of a firm shapes the formulation and establishment of sustainability policies, choices for actions, implementation, monitoring, and associated accountability. These are influential factors to shape the intention to action towards sustainability. For example, the United States did not ratify the Kyoto Protocol while most countries in Europe made their commitment, leaving to implementation of different compliance and reporting standards for firms in the United States and Europe (Levy and Newell 2000). Similarly, recent policy level decision by the United States to withdraw from the erstwhile Paris Agreement has led US firms to see the risks and effects of climate change differently than other countries. These developments, along with the formal and informal institutional settings (Doh and Guay 2006) in different countries are expected to influence firms' adherence to different sustainability practices and norms, and the subsequent benefit accrual from green IS implementations and verifications. Although researchers studied the different impacts of institutional settings on corporate sustainability strategy (e.g., Diebecker and Sommer 2017), the exploration of institutional and policy level differentiated impacts on the effects of green IS implementations and verifications remains a wide gap in the existing information systems research, that this study tries to address.

We ask this research question: *how do green IS implementation and standards-based verification influence the relationship between climate change risk perception and carbon disclosure performance, in different institutional settings?* We argue that depending on the institutional environment, the moderating effects of green IS implementation and verification type are different. More specifically, more advanced green IS implementation and external verification have a positive influence on the relationship between climate change risk perception and carbon disclosure performance for firms in the United States, while such influences are negative for EU firms.

We first propose and discuss a framework of green IS in the sustainability governance process, which illustrates the process from climate change risk perception to value creation for the firm. We then propose our conceptual model and hypotheses that aim to explore the influence of green IS implementation and verification on the relationship between climate change risk perception and carbon disclosure performance of a firm, by considering the institutional setting the firm is situated in. We matched archival data of different firm samples from multiple sources to test our hypotheses. The empirical analysis to test the hypotheses involves a baseline ordinary least square (OLS) estimation and a two-stage least square (2SLS) estimation with instrument variable to address endogeneity issues. We find significant and positive moderating effects of green IS implementation and verification on the relationship between climate change risk perception and carbon disclosure performance of US firms. For EU firms, we only find a significant but negative moderating effect of verification against standards. This study contributes to IS literature in suggesting and validating the role of green IS in the sustainability governance process and comparing it

across two institutional settings. We discuss the implications of our findings and the theoretical and managerial contributions of this study.

Background and Theoretical Development

Green IS in Sustainability Governance

Existing research suggests that green IS can play an important role in shaping beliefs about the environment, enabling or transforming sustainable processes and practices in organizations, and improving environmental and economic performance (Melville 2010); and indicates that organizations can use such systems to achieve sustainable development goals while improving productivity, reducing costs, and avoiding poor environmental practices (Joshi and Li 2016). Firms need to have the right intentions, embedded explicitly in the contexts, to be effective in environmental compliance, without which the practices may result in operational waste, energy inefficiency, wasted resources, and increased emissions (Benitez-Amado and Walczuch 2012; Kroes et al. 2012).

Dyllick and Muff (2016) proposed a business sustainability framework that has three components: input, process, and output. The input part is about what businesses consider as sustainability concerns, the process part asks questions such as how to manage risks and opportunities and how to embed sustainability throughout the organization from the organizational perspectives, and the output part has focused on the values created through business sustainability governance. The authors suggested that these are different approaches to business sustainability, and in most cases, each approach is discussed separately. This study develops the framework of green IS in the sustainability governance process in Figure 1, which integrates the input, process, and output.

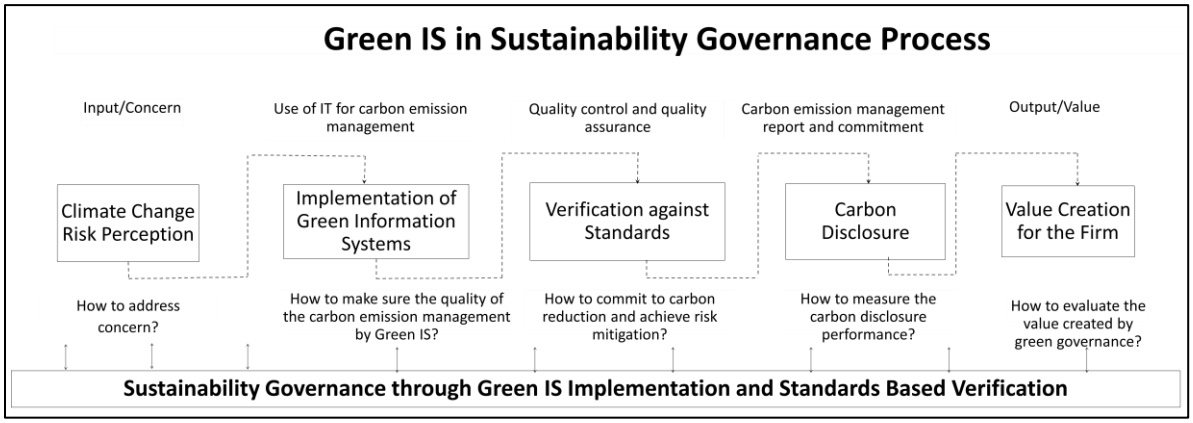

Figure 1. Green IS in Sustainability Governance

The specific concern in the proposed framework of this study is the long-term climate change risk perception; the output of this framework is the value creation for the firm. The core element of our framework is the how part, that is how green IS (both implementation and verification) contribute to the carbon disclosure performance in an organization. This figure shows the path from risk identification to value creation of a firm in the climate change context. There are two parts of each step: the top row highlights the main content of each step, and the bottom row proposes the how question that links each step and its next step. This comprehensive framework can also be applied to generic sustainability governance contexts.

The importance of sustainability governance is emerging as businesses need to embed sustainability throughout the organization by considering the strategies, governance, organizational culture, and auditing & reporting systems (Dyllick and Muff 2016). Sustainability governance can be leveraged through the intensive information capability and opportunity brought in by green IS. Green IS provides opportunities in facilitating environmentally sensitive human behavior, and can be used to monitor and evaluate the behavioral and environmental impacts (Midden et al. 2007). It is highly likely that IT, as usual, will play a crucial role at some stage such as modeling, management, coordination, monitoring, evaluation, and reporting (Higgs et al. 2008). Green IS, in this context, supports a firm to improve business process

management and create a sustainable environment (Butler 2011). Green IS can be applied in various different areas, such as monitor and report GHG emission, control and report the waste, manage energy consumption in transportation and building, assist to design greener products, and redesign the overall business process in the company, in order to achieve the environmental sustainability. Moreover, green IS may include the upgraded IT-based platform to support the business process to be environmentally sustainable (Butler and McGovern 2012). However, to leverage all these for a firm, a high-level lever is necessary; that can be provided at the governance level. A combination of green IS and sustainability governance process is feasible to provide a comprehensive systemic perspective to the structural, process, and relational parts (Peterson 2004); that can then percolate to the strategic and tactical issues within organization, such as internal transfer for emission reduction, supply-chain management, and acquisition of emission credits (Kolk and Pinkse 2005).

Thus, our theoretical framework, as presented in Figure 1, provides the high-level representation of green IS within the broad sustainability governance process. In this process, the importance of prior discussed data governance (Tallon 2013) is embedded within the verification. The proposed framework is a stepwise process that starts with the implementation of green IS, followed by the verification and subsequent carbon disclosure performance.

Institutional Contexts for Green IS in Sustainability Governance

The institutional embeddedness in the sustainability governance context is important as the external environment plays a significant role in the value creation process of a firm. Institutional context determines the nature of stakeholders and the importance they place on sustainability; that, in turn, determines the approach, direction, and modalities for sustainability governance of a firm.

Prior research suggests that temporal, sustained, and average competitive advantages, as well as disadvantages (i.e., negative competitive advantage) (Wade and Hulland 2004) are relevant for firms' positioning, dynamics, and overall long-term performance (Agarwal and Selen 2009). However, environmental volatility, hostility, complexity and similar factors (Chen et al. 2014; Saldanha et al. 2013; Tallon and Pinsonneault 2011) determine how firm positions itself to manage or mitigate risk using any sort of IT-enabled strategy or governance for better performance. Arguably, the implications of IT-enabled strategy and governance are also salient to develop a response and reaction to the uncertain external environment by mitigating risk. Uncertainty and competitive rivalries force firms to pursue different strategies, aligned to different institutional arrangements (Tallon 2007); and moreover, aligns different strategies and actions to respond or shape firm's future path (Chan et al. 2006; Palmer and Markus 2000; Tallon 2008). In the context of this study, as described earlier, we argue that the alignment of risk perception to climate change, green IS implementation, and verification against standards influences the carbon disclosure performance of a firm. Also, we posit the institutional setting as one additional element that influences the sustainability governance process through beliefs, regulations, and policies (Doh and Guay 2006).

We instantiate the institutional differences in this study across the United States and Europe, based on three foundations discussed in prior research (Levy and Newell 2000). *First*, Europe has been concrete on the sustainability concerns and responsible actions, to include it as part of national identity and heritage. Europeans have raised concerns against the regarding unforeseen risks, and the economic and environmental issues have been compatibly considered. On the contrary, the US approach to sustainability has been more about economic costs of regulation and technical solutions, and the relationship between growth and sustainability is considered as a zero-sum approach (Doh and Guay 2006).

Second, the political approach to sustainability in the US is open to competing interest groups, whereas, EU context is a more collaborative approach over issues. Institutions in Europe do not face significant public scrutiny like in the US and are often insulated from popular press and opinions. This has resulted in Europe having a tougher stance and action plan for environmental issues than the US. However, the stringent actions by the US are often criticized for being unrealistic and highly difficult for businesses to adopt. On the contrary, US businesses have been calculative towards environmental actions, including intensive campaigns against regulatory controls for emissions and other sustainability relevant policies. These contexts are important while reflecting on the US and EU approaches to sustainability, to some extent discussed in prior research within the frames of corporate social responsibility (Diebecker and Sommer 2017).

Third, institutional setting differences are results of the stakeholders' relationship, while on the other hand, the differences are reflected and have impacts on the interactions between stakeholders such as corporate sustainability governance. Jackson and Apostolakou (2010) tested and found the different impacts of institutional environment on firms' sustainability activities. More specifically, they concluded that institutionalized stakeholder involvement substitutes for explicit corporate sustainability practices by applying the neo-institutional theory and comparative institutional analysis in the sustainability governance context. They categorized the differences between liberal market economies and coordinated market economies. As situated in a liberal market economy, US firms often receive financing from large equity markets, where often have strong disclosure requirements. The carbon disclosure will complement such requirement and need.

Thus, broadly, the institutional setting differences between the US and the EU are reflected through at least three dimensions: political leadership, public understanding, and societal norms. The EU has established an international leadership in sustainability policies since the early 1990s (Oberthür and Roche Kelly 2008), while the US government withdrawal from the 2015 Paris Agreement on climate change mitigation. Regarding sustainability issues such as climate change, there are significant differences in public understanding across the two sides. For example, survey results showed that while a high percentage of the UK respondents are very convinced world climate change, the percentage of such respondents was quite low in the US (Weber and Stern 2011). The differences in understanding and approach are argued to be already embedded in culture and legacy more in EU than the perception in the US to take a non-sustainable orientation with highly resource-consuming orientation across the citizens (Aguilera et al. 2006; Confino 2011; Rosenthal 2014).

To summarize, we note that: (1) the difference between approaches to sustainability in US and EU firms should be discussed with specific contexts, if not too generic. In this study, our context is green IS in sustainability governance. (2) The institutional differences are not fixed; they are changing over time, i.e., Kyoto protocol time period and the Paris agreement period may differ; and therefore, opens new challenges in terms of concurrent investigations. (3) Although the reasons for the different institutional environments have been studied, the results of such difference are largely not investigated, especially by considering the role of green IS, that the current study tries to fulfill.

Conceptual Model and Hypotheses

We posit a conceptual model with three sets of relationships. Prior literature has demonstrated the positive relationship between risk perception and firm performance (Boermans and Willebrands, 2017). Thus in this study, we aim to explore how the interaction of green information system (GIS) and climate change risk intensity perception (RIP), and the interaction of verification against standard (VAS) and RIP will influence a firm's carbon disclosure performance score (CDPS), considering the different institutional settings in which the firm is situated. Figure 2 presents our conceptual model.

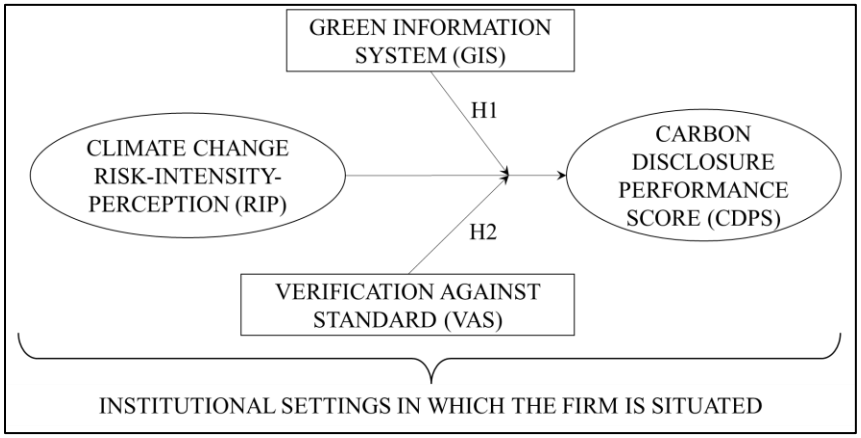

Figure 2. Research Model

Prior studies mainly focused on an individual's personal risk perception regarding climate change. We argue that in the organizational level, a firm also has its own perception on the climate change-related risks.

There are different types of risks posed by climate change to businesses and firms in a different industry may feel a different level of risks (Engel et al. 2015). In this study, we focus on three types of climate change-related risks, i.e., physical risk, which refers to the damage caused by extreme weather events on a firm's infrastructure, factories, and other operations; regulatory risk, which is about the risk caused by the government action changes such as new rules to add cost and forbid certain operational activities, because of the climate change; and general risk, which refers to any other types of climate change-related risks, such as prices risk, product risk, ratings risk, and reputation risk. Some firms may feel part or even no risk due to climate change, while some firms may perceive multiple types of climate change-related risks. According to how many types of climate change-related risks a firm perceive, there is variety in the climate change risk-intensity-perception (RIP).

Carbon emission is the main reason for the human-made climate change hazard. Thus carbon emission reduction is one of the most important climate change strategies to mitigate the perceived risks. Firms may adopt information systems to facilitate carbon emission management and reduction (i.e., green IS). Green IS has a wide range of technical architectures, from basic spreadsheet to advanced specialized system, and more advanced software network (Melville et al. 2017). The interaction of RIP and GIS may lead to a better output of the carbon disclosure performance. For example, two identical firms have the same level of RIP, if one firm applies basic green IS such as spreadsheet, and another firm applies advanced green IS such as a carbon emission management software package to manage the carbon emission, the latter firm may do better carbon disclosure, which reflected by its carbon disclosure score.

This is especially true for firms in the informal institutional setting (e.g., US firms). *First*, these firms concern more about their economic costs which could be reduced by efficiently leverage the implementation of green IS. *Second*, as situated in the liberal market economy, it is critical for US firms to obtain financial support from stakeholders, who value the public disclosure. As a result, the US firms will try all the best to utilize green IS and improve their carbon disclosure performance for maintaining or increasing the market equity. *Third*, it is suggested the corporate governance structure of US firms is mostly monistic management model, that is the combined management and governance structure (Diebecker and Sommer 2017). Therefore, there is no gap between sustainability governance and green IS implementation practices. In other words, the consistency of strategy and business activities increase the efficiency and effectiveness of green IS implementation in US firms for their carbon disclosure performance.

However, we argue that the situations for firms situated in the formal institutional setting (e.g., EU firms) are different. *First*, the EU firms may implement green IS because of formal institutions such as regulatory pressures, and cause decoupling between adoption and usage (Greenwood et al. 2017). In other words, even the firm has the most sophisticated systems; it may not bring a better outcome for the firm. The best case is no influence while in some worse cases, the adoption of green IS may hinder and complicate firms' carbon disclosure process, thus results in decreased carbon disclosure score. *Second*, the EU firms do not rely on the capital market such as stock or bank loan heavily (Diebecker and Sommer 2017). Thus, they do not have the motivation to increase public disclosure for more funding through the proper implementation of green IS. *Third*, the typical corporate governance structures in EU firms are dualistic approaches, which separate the management and governance, leading to the disconnection between sustainability governance and sustainability practices such as the use of green IS. Therefore, we have the following two hypotheses:

Hypothesis H1a: (RIP, GIS, Interaction-US): *The climate change risk-intensity-perception (RIP) and the implementation of green information systems (GIS) interact to influence carbon disclosure performance score (CDPS) positively in a sustainability-relevant informal institutional environment.*

Hypothesis H1b: (RIP, GIS, Interaction-EU): *The climate change risk-intensity-perception (RIP) and the implementation of green information systems (GIS) interact to influence carbon disclosure performance score (CDPS) negatively in a sustainability-relevant formal institutional environment.*

Carbon emission management is a detailed-oriented and protocol-guided process. To make sure the quality, verification against carbon emission management standards (VAS) is a necessity (Qian et al. 2018). With this governance practice, firms are expected to have better carbon disclosure performance. Generally, there are two types of verification, either conducted by the firm itself or outsourced to the third party for external verification. Here we argue that compared to internal verification, external verification could generate a better outcome. The possible reasons could be the expertise, unbiased attitude, and the efficiency of the third-party verification organizations (Matisoff et al. 2013). In summary, we anticipate the external

verification could lead to better carbon disclosure quality and performance of firms, more specifically, of firms in the informal institutional settings (e.g., US firms) for several reasons. *First,* carbon emission management relevant policies and standards are relevantly new in informal institutions (Oberthür and Roche Kelly 2008). The individual firm generally does not have sufficient ability to conduct internal verification of their carbon emission calculation. Compared to internal verification, the external verification provided by professional organizations can enhance their carbon disclosure quality significantly. *Second*, US firms need accurate data to do intense campaign and lobby work to influence the national level policymaking. The third-party verified results satisfy such needs. Although US firms did not intend to improve carbon disclosure performance through external verification, we propose such a positive moderating effect.

On the other hand, the change from internal verification to external verification for firms in the formal institutional setting may have a negative influence on the relationship between climate change risk perception and carbon disclosure performance. For example, EU firms may go for external verification as required, but this action will lead to no carbon disclosure performance improvement. Instead, compared to no verification or just internal verification, firms that conducted external verification may think they already done enough work, thus decide not to do the voluntary carbon disclosure. *Furthermore*, in the last decades, firms have accumulated carbon disclosure standards expertise internally. Compared to external verification, these firms can improve carbon disclosure performance through internal verification with the internal knowledge of business processes. *Moreover*, the relationship between business and government in Europe is more collaborative (Diebecker and Sommer 2017); thus, there is no need to pay for external verification, as the internal verification can be the cooperation outcome of EU firms and governments. Based on the above discussion, we hypothesize that:

Hypothesis H2a: (RIP, VAS, Interaction-US): *The climate change risk-intensity-perception (RIP) and the verification against standards (VAS) interact to influence carbon disclosure performance score (CDPS) positively in a sustainability-relevant informal institutional environment.*

Hypothesis H2b: (RIP, VAS, Interaction-EU): *The climate change risk-intensity-perception (RIP) and the verification against standards (VAS) interact to influence carbon disclosure performance score (CDPS) negatively in a sustainability-relevant formal institutional environment.*

Arguably, GIS may influence the VAS decision. For example, firms have implemented very advanced green IS may think the system can provide enough accurate and complete carbon emission management, thus will not do further verification. However, such an association is beyond the focus of this study.

Methods

The data analysis is used to evaluate what is the moderating effects of green IS implementation and the verification against standards on the relationship between the climate change-related risk perception of a firm and its carbon disclosure performance, depending on its institutional environment.

Data and Variables

This study uses secondary datasets from two sources, including CDP (carbon disclosure project, www.cdp.net) and Compustat database. CDP is a non-profit initiative that conducted an annual survey on firms' carbon emission related risks and strategies from 2003 (Matisoff et al. 2013). The questionnaire mainly includes four parts: climate change-related risks and opportunities, emission calculation and verification, performance, and governance (Guenther et al. 2016). Based on firms' responses, CDP also calculates and reports the carbon disclosure performance of the global fortune 500 firms (Cotter and Najah 2012). Compustat is a widely used database that contains financial information about global companies.

The variables used in this study are described in table 1. Carbon disclosure performance score (CDPS) is the score calculated by CDP for Global Fortune 500 firms based on their responses to CDP's annual questionnaire. It ranges from 0 (no answer) to 100 (full answer), indicating the information quality of a firm's carbon disclosure. We follow previous literature (Ben-Amar and McIlkenny 2015; Qian et al. 2018) and use it as the dependent variable in our study.

Table 1. Variables Table		
Variable	**Description**	**Source**
CARBON DISCLOSURE PERFORMANCE SCORE (CDPS)	Calculated by CDP for Global Fortune 500 firms based on their responses to CDP's annual questionnaire. It ranges from 0 (no answer) to 100 (full answer), indicating the information quality of a firm's carbon disclosure. The baseline estimation models used the data from the year 2011.	Carbon disclosure project, 2011.
RISK-INTENSITY-PERCEPTION (RIP)	The level that a firm considers climate change as a risk. It is a summative index that captures firms' attitudes towards different types of climate change-related risks, such as regulatory, physical, and general risks. *Coding scheme*: This variable is coded as 0 if the firm does not consider climate change as a risk, as 1 if the firm considers any one type of risk, as 2 if consider two types of risks, 3 if consider three types of risks.	Carbon disclosure project, 2009.
GREEN INFORMATION SYSTEM (GIS)	Calculation systems used by the firms to manage carbon emission. *Coding scheme*: This variable is coded as 0 if no such system, as 1 if used very basic systems such as Excel, as 2 if used basic systems that are specialized tools, as 3 if used basic systems that embedded multiple protocols, as 4 if used somehow advanced systems such as environment management systems, as 5 if used advanced systems such as web-based online systems.	
VERIFICATION AGAINST STANDARDS (VAS)	The process conducted by the firms to assure the carbon emission calculation quality. *Coding scheme*: This variable is coded as 0 if no such process, as 1 if conducted internal verification, as 2 if conducted external/3rd party verification.	
FIRM SIZE	Log of the firm's total assets	Compustat, 2009
PROFITABILITY	Log of the firm's total sales	
INTANGIBLE	Log of the firm's total intangible assets	
INVENTORY	Log of the firm's total inventories	

Climate change-related risk-intensity-perception (RIP) is coded based on firms' answer to CDP's questionnaire on three types of climate change-related risks, i.e., regulatory, physical, and general risks. It is a summative index that captures the intensity a firm considers climate change as a risk. This variable is coded as 0 if the firm does not consider climate change as a risk, as 1 if the firm considers any one type of risks, as 2 if consider two types of risks, and as 3 if consider three types of risks. Green IS (GIS) is based on the content analysis of firms' answers to the CDP survey about calculation systems used by the firms to manage carbon emission. This variable is coded as 0 if there is no such system, as 1 if firm used very basic systems such as Excel, as 2 if firm used basic systems that are specialized tools, as 3 if firm used basic systems that embedded multiple protocols, as 4 if firm used somehow advanced systems such as environment management systems, as 5 if firm used advanced systems such as web-based online systems. More details of the coding scheme can be found in Appendix Table. To assure the validity of this coding scheme, besides the literature review, we first had an expert panel from sustainability organization to discuss the categories of IS for carbon emission management. Further, three researchers conducted the coding separately. We tested the inter-rater reliability with Cohen's kappa coefficient, and the value of 0.87 suggests a strong level of agreement (Boudreau et al. 2001). Verification against standards (VAS) is about the process conducted by the firms to assure the carbon emission calculation quality. Based on responses of firms to CDP survey, this variable is coded as 0 if there is no such process, as 1 if firm conducted internal verification, as 2 if firm conducted external/third-party verification. Control variables of this study include the firm size that measured by the log value of firm's total assets, profitability that measured by the log value of firm's total sales, the level of a firm's intangible assets and its inventory (Luo and Tang 2014; Qian et al. 2018).

The focus of this study is the institutional environment differences across the US and EU. So, we have two corresponding samples for the analysis. Table 2 presents the summary statistics and correlations table, separated by the sample of firms from the US and the EU. For the US sample firms, the average carbon disclosure score is 73.43; firms generally have relatively high-risk intensity perception (2.33/3); the average level of the green IS implementation is slightly high (2.69/5); the percentages of internal verification and

external verification are almost equal (1.19/2). European firms are firms from Denmark, Finland, Germany, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, and the UK. The average carbon disclosure score of the firms in this sample (85.28) is much higher than the US sample; EU firms also generally have quite a high-risk intensity perception (2.81/3); the average level of the green IS implementation is in the medium level (2.56/5); the percentages of internal verification and external verification are very similar (1.18/2).

Table 2. Summary Statistics and Correlations Table

US-Sample Firms

			Obs	Mean	SD	Min.	Max.	*1*	*2*	*3*	*4*	*5*	*6*	*7*
US-Sample	*1*	*CDPS*	42	73.43	15.60	34	98	1.00						
	2	*RIP*	42	2.33	1.10	0	3	**0.31**	1.00					
	3	*GIS*	42	2.69	1.49	0	5	**0.28**	-0.20	1.00				
	4	*VAS*	42	1.19	0.45	0	2	0.02	0.02	0.13	1.00			
	5	*SIZE*	42	10.52	0.88	8.63	12.50	-0.01	0.11	0.13	0.18	1.00		
	6	*PROF.*	42	10.03	1.13	6.49	12.90	0.08	0.05	0.14	0.06	**0.81**	1.00	
	7	*INTAN.*	42	7.53	2.87	0	11.81	-0.09	-0.16	-0.23	-0.18	**0.28**	**0.37**	1.00
	8	*INVEN.*	42	7.10	1.58	0	10.45	0.18	**0.30**	-0.02	0.08	**0.37**	**0.48**	0.02

EU-Sample Firms

			Obs	Mean	SD	Min.	Max.	*1*	*2*	*3*	*4*	*5*	*6*	*7*
EU-Sample	*1*	*CDPS*	32	85.28	9.86	63	99	1.00						
	2	*RIP*	32	2.81	0.59	0	3	**0.25**	1.00					
	3	*GIS*	32	2.56	1.46	0	5	**0.35**	**0.31**	1.00				
	4	*VAS*	32	1.28	0.46	1	2	-0.17	**-0.39**	-0.25	1.00			
	5	*SIZE*	32	11.08	0.82	9.07	12.75	0.002	0.03	-0.05	-0.07	1.00		
	6	*PROF.*	32	10.67	0.90	8.60	12.54	0.11	-0.09	-0.04	0.08	**0.87**	1.00	
	7	*INTAN.*	32	8.92	1.15	5.97	11.22	-0.20	0.20	-0.05	-0.02	**0.37**	**0.37**	1.00
	8	*INVEN.*	32	8.00	1.40	4.80	10.22	0.06	-0.24	0.11	0.25	**0.68**	**0.72**	0.16

We have noticed that in the correlations tables, the correlation between size and profitability are quite high, though they are two completely different measures. The correlations in bold indicate significance at the 10% level. As suggested in previous literature, the correlation table indicates the positive relationship between risk intensity perception (RIP) and carbon disclosure performance score (CDPS), in another word, if a firm reported higher RIP, it got higher disclosure score. A similar correlation exists between green information system (GIS) and CDPS.

Estimation Model

This study applies the cross-sectional OLS (ordinary least square) regression model as the baseline model to estimate the coefficients. The model specification is:

$$Y_i = \boldsymbol{X_i}\beta + \varepsilon_i$$

Where Y represents dependent variable (i.e., carbon disclosure score in this study), $\boldsymbol{X}$ represents a vector of factors, such as the risk, system, verification, and control variables; β is a vector of parameters to be estimated, and ε is the error term associated with each observation i.

Specifically, we used the following model specification to test our two hypotheses, i.e., the moderating effects of the green are and verification on the relationship between risk and carbon disclosure score.

$$CDPS = \beta_0 + \beta_1 RIP + \beta_2 GIS + \beta_3 VAS + \beta_4 RIP \times GIS + \beta_5 RIP \times VAS + \beta_6 SIZE + \beta_7 PROF + \beta_8 INTAN + \beta_9 INVEN + \varepsilon$$

We estimated the model with the two interaction terms and control variables for US and EU sample separately to test our hypotheses.

Estimation Results

Table 3 provides the baseline OLS estimation results with heteroskedasticity-consistent robust standard errors. The first model (column 1) shows only direct effect for US firms while the second model (column 2) presents the direct effect results of EU firms. The results confirmed the positive relationship between risk perception intensity and carbon disclosure performance in both samples (Boermans and Willebrands, 2017). The direct effects of GIS on CDPS are not consistent across the US and EU firms while the direct effects of VAS are not significant in both samples. In the current study, we do not hypothesize the direct effects of RIP, GIS, nor VAS on CDPS. The first two models just provide discussion base for the focused interaction effects.

Column 3 of Table 2 shows results for US firm sample with the focus on the two interaction terms. We find both interactions which reflect the moderating effect of green IS implementation (RIP × GIS: β=3.625, p<0.05), and moderating effect of verification against standards (RIP × VAS: β=17.517, p<0.01), are significant and positive on the relationship between climate change-related risk perceptions and carbon disclosure score of US firms. These findings support both H1a and H2a. In other words, for firms located in the US, with one level of GIS upgrade, the firm's carbon emission disclosure score increases 3.625 points on average. Moreover, compared to the internal verification, the firm chose external verification could improve its carbon emission disclosure score 17.517 points averagely.

Table 3. Baseline Estimation Results-OLS

	Direct Effect Models		Interaction Effect Models	
	(1)	(2)	(3)	(4)
	US firms	EU firms	US firms	EU firms
VARIABLES	CDPS	CDPS	CDPS	CDPS
RIP	5.867***	4.747**	-27.395**	32.260***
	(1.945)	(1.856)	(10.653)	(11.264)
GIS	4.178***	1.491	-6.226*	7.189
	(1.452)	(1.508)	(3.441)	(13.034)
VAS	0.725	-2.125	-47.919***	34.741***
	(6.420)	(4.403)	(12.056)	(11.549)
RIP × GIS			**3.625****	-2.066
			(1.462) H1a	(4.194) H1b
RIP × VAS			**17.517*****	**-13.103****
			(4.875) H2a	**(5.146) H2b**
Size	-5.871	-5.793	-5.200	-7.336
	(4.478)	(4.143)	(3.954)	(4.333)
Profitability	2.754	7.575	2.013	7.844
	(4.536)	(4.434)	(3.878)	(4.738)
Intangible	0.506	-2.794	0.695	-2.373
	(0.894)	(1.648)	(0.875)	(1.872)
Inventory	0.822	0.034	1.843	0.897
	(1.165)	(1.939)	(1.162)	(2.042)
Constant	72.133***	78.873**	156.980***	4.522
	(26.423)	(32.147)	(32.359)	(36.102)
Observations	42	32	42	32
R-squared	0.268	0.308	0.382	0.350

*Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, *p<0.1*

However, we find the opposite results in model 4 for EU firms. The moderating effect of green IS implementation (RIP × GIS: β=-2.066) is negative but not significant. However, the verification against standards has a significant and negative moderating effect (RIP × VAS: β=-13.103, p<0.05) on the relationship between climate change risk perception and carbon disclosure score.

Robustness Checks

We conducted additional analyses to check the robustness of our baseline estimation results. First, because of the self-reporting nature of the green IS implementation, we should concern the potential endogeneity issues (Luo and Tang 2014; Tang and Luo 2014). To address this concern, we used an instrumental variable approach to test for endogeneity and to estimate the model using two-stage least-square (2SLS). Following the previous literature that uses industry IT intensity as an instrument for firm IT intensity (e.g., Kleis et al., 2012), we use average industry GIS as an instrumental variable for GIS. The rationale is that industry use of GIS may influence firm use of GIS but not influence carbon disclosure score directly. We conduct an instrumental variables regression using 2SLS estimation. The results for US and EU firms are consistent with the baseline OLS estimation results. Furthermore, the dependent variable in the main analysis is from the year 2011 dataset (CDPS2011). We use the carbon disclosure score of firms in the year 2012 (CDPS2012) to check the sensitivity of our results (He et al. 2013). We find that the OLS estimation with CDPS2012 as dependent variable provides consistent results with the main effects. These results indicate the causal inferencing of our findings. Because of the dependent variables are lagged results of the explanatory variables (in the year 2009), we do not need to concern the reverse-causality issues.

Discussion

Main Findings

This study proposes the framework of green IS in sustainability governance, consisting of the alignment across climate change risk perception, green IS implementation, and verification against standards on firms' carbon disclosure performance. Also, the conceptual framework suggests the institutional environment as an additional factor in shaping these relationships. By discussing the institutional contexts for green IS in sustainability governance, we proposed two sets of hypotheses with the aim to explore the moderating effects of green IS (GIS) and verification again standards (VAS) on the relationship between a firm's climate change risk intensity perception (RIP) and its carbon disclosure performance measured by score (CDPS), based on different institutional settings a firm is situated in. We used secondary data of the US and EU firms to test our hypotheses. We found the consistent differences between the US firms and the EU firms.

For the sample of US firms, we find significant and positive moderating effects of both GIS (H1a) and VAS (H2a). These findings indicate that for firms that belong to informal institutional settings, the more advanced green IS they implement for the carbon emission management, the better carbon disclosure performance that reflected by the score they could get. Also, for these firms, compared to no verification and internal verification of carbon emission management, external verification will result in better carbon disclosure performance. These findings are consistent with the suggested characteristics of the institutional environment that US firms situated, including the cost reduction-oriented intention, the liberal market economy, and the monistic corporate governance structure (Diebecker and Sommer 2017). However, for the sample of EU firms, we only find the interaction of RIP and VAS is significantly negative (H2b) while we do not find support to the hypothesis H1b on the interaction effect of RIP and GIS. This implies that firms in a formal institutional environment, the external verification of carbon emission management can hinder their carbon disclosure performance. The reasons for these results can be no strong motivation for public disclosure, historical expertise accumulation, and collaboration outcome between EU firms and governments. The potential reason for the non-significant moderating effect of RIP and GIS interaction maybe even there is decoupling between green IS adoption and usage, this decoupling effect does not hinder EU firms' carbon disclosure performance (Greenwood et al. 2017).

Contribution

Exploration of the role of green IS in sustainability governance is a niche area, both from practical and academic perspectives. This study proposes a comprehensive framework of green IS in sustainability governance, with the realization that firms are gearing up with the sense and response to climate change. Such response is motivated from risk-internalization, i.e., how best to identify and response to climate change-related risk; and from external-stakeholders' demands. In any case, firms that have a preparedness to climate change would always be the forerunners when it comes to reporting environment relevant

indicators, such as, in the context of this study, the carbon disclosure. However, investigation of the role of green IS, including implementation and verification to assure the quality control in the sustainability governance process is missing in the existing literature. By addressing the gaps in previous literature, this study provides both theoretical and empirical contribution.

More specifically, this study provides several research contributions. *First*, based on prior literature (Dyllick and Muff 2016), we proposed a comprehensive framework of green IS in sustainability governance process which is used in the carbon emission management context in this study. This framework could be applied to illustrate the role of green IS in various use cases. The bottom line is the alignment of three components: sustainability issue, green IS implementation, and organizational governance. *Second*, our findings highlight the significance of the institutional environment variations. Prior literature has suggested the influence of macro environment on the IT business value (Melville et al. 2004). Although researchers also showed the differences across institutional settings on sustainability management and governance (e.g., Diebecker and Sommer 2017, Levy and Newell 2000), such exploration is missing in IS research. We empirically demonstrated the impacts of such institutional differences on the effect of green IS, and thus shed light on the necessity to distinguish or control such effects. *Third*, we provided a detailed discussion across two different institutional settings (US vs. EU) by consolidating the policy, economy, governance structure, and other relevant factors. With the distinction beyond cultural difference dimensions (Hofstede 1983), this study offers a useful reference for future across-nation research.

This study and its somehow counterintuitive findings also offer important practical contribution and implications. *First*, in a formal institutional setting, firms may adopt green IS because of the external pressure, but the decoupling of green IS adoption and usage may exist. In other words, the adoption of green IS becomes a format. Therefore, instead of high external pressure, formal institutions should find methods to improve firms' internal motivation. For example, education and incentive can be part of the solutions. *Second*, the alignment of sustainability governance and sustainability action/practice is the key to the anticipated sustainability outcome. Firms that apply dualistic governance approach may balance the combination of governance and management to connect the strategy and practices seamlessly. *Third*, for firms in coordinated market economy and who do not rely heavily on stakeholders, policies that could motivate the public disclosure should be developed and promoted. *Fourth*, there is no single correct answer to the build or buy question (e.g., internal verification vs. external verification); firms should make decisions that suit their cases.

Limitations and Future Research

Besides the contribution of this study, there are some limitations to this current exploratory study. *First*, the coding of green IS and verification is from content analysis based on firms' self-reported response to the annual CDP survey. We used multiple methods such as coding reliability test and instrument variable to address this limitation, but we plan to get more objective data on these two factors in the future study. *Second*, this study only uses a single year data and relatively small samples to test our hypotheses. This data limitation results in the generalization issue for our findings. For example, the results cannot reflect the policy changes across the years. In the future, we will try to use multiple years panel data and large sample size to get more robust results. *Third*, the current study only considers the impacts of climate change risks, while climate change could also be opportunities for some firms. In a future study, we will incorporate climate change-related opportunities to have more comprehensive research. *Moreover*, besides the focused variables and institutional setting, there are many other factors such as learning or adoption ability, corporate culture regarding risk response, and employee attitudes of a firm may influence its carbon disclosure performance. We may include these relevant factors in future research.

In conclusion, this study explored the role of green IS in the sustainability governance process and empirically tested the moderating effects of green IS implementation for and verification of carbon emission management on the relationship between a firm's climate change-related risk intensity perception and its carbon disclosure performance, under two different institutional settings. By using secondary data, we tested and validated our hypotheses, indicating the significance of the institutional environment and the role of green IS implementation and different types of verification. Overall, this study provides both theoretical and practical implications for the research and practice on green IS for sustainability.

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Appendix Table A1: Green IS coding scheme

Coding	**0**	**1**	**2**	**3**	**4**	**5**
Description	No system	Very basic system	Basic system designed	Basic system embedded multiple protocols	Somehow advanced system	Advanced system
Distinct features	-	Gather carbon emission data manually	Compile carbon emission data in certain context such as electricity and water sector	Standardize the carbon emission against the protocols	Understand the carbon emission in a comprehensive manner	Predict the carbon emission for low-carbon strategies
Examples	-	Excel spreadsheet	Specialized tool		Environment Management System	Web-based online system
Cases	AFLAC Incorporated *"No calculation tools were used"*	Altria Group, Inc. *"Excel based data system to calculate GHG"*	Woolworths Limited *" has an in-house inventory calculation tool "*	Royal Bank of Canada *"The majority of GHG emissions are calculated based on the methodologies provided by the GHG Protocol"*	Volkswagen *"The calculation tool used is part of our Environment Management System"*	Accenture-*Enablon software*; Chevron-*SANGEA software*
Functions	-	Data retrieval	Information retrieval	Information extraction	Knowledge creation	Intelligence formation
Types	-	Calculation	Analysis		Description	Prediction
References	Melville et al. (2017), Andrade Rojas et al. (2016)					

Note: to assure the validity of this coding scheme, on top of the literature review, we first had experts panel from sustainability organization to discuss the categories of IS for the carbon emission management. Further, three researchers conducted the coding separately. We tested the inter-rater reliability with the Cohen's kappa coefficient, and the value of 0.87 suggests a strong level of agreement (Boudreau et al. 2001).