# The effect of IS-related human capital and CIOs in top management teams on green IS innovation activities

Manfred Strehlow
*University of Munester*, mstrehlow@uni-muenster.de

Colin Schulz
*University of Muenster*, colin.schulz@uni-muenster.de

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*Completed Research Paper*

**Manfred Strehlow**
University of Muenster
Geiststraße 24, 48151 Münster
mstrehlow@uni-muenster.de

**Colin Schulz**
University of Muenster
Geiststraße 24, 48151 Münster
colin.schulz@uni-muenster.de

## Abstract

*Climate change and the fast-changing natural environment necessitate firms to adapt their way of doing business towards environmental sustainability. As information systems (IS) are seen as a potential lever to facilitate this adaptation successfully, this study focuses on the role of IS-related human capital of top management team (TMT) members in facilitating green IS innovation activities in firms. Using a panel data set of firms listed in the S&P 500 index, this study finds that IS-related education and experience of TMT members are positively associated with green IS innovation activities. In addition, the results show that the presence of a CIO positively moderates the positive association of IS-related experience with green IS innovation activities. Consequently, this study contributes to the IS literature on the intersection of human capital theory from an upper echelon perspective and environmental sustainability.*

**Keywords:** Green IS innovation, IS-related human capital, Top management teams

## Introduction

The accelerating climate change and a resulting fast-changing natural environment are rising concerns for the global economy and require firms to adapt their way of doing business towards environmental sustainability (IPCC 2022). To enable this adaptation, research calls for enhanced activities in this area to pave the way towards environmentally sustainable operations and products and consequently to facilitate environmental sustainable, also known as green, innovation activities (Burke et al. 2016). In extant research, scholars claim that the success of this transformation depends on the capability to learn, innovate, and change (Elliot 2011). This dependency results in a requirement for a broader knowledge base compared to non-green initiatives, and let research call for specific insight into which capabilities are needed to facilitate green innovations (Barbieri et al. 2020; Consoli et al. 2016).

The Intergovernmental Panel on Climate Change (IPCC 2022) sees information systems (IS) and related capabilities as potential lever to implement this transformation successfully. Academics follow this argumentation and claim that IS can constitute a promising contributor to achieve environmental sustainability (e.g. Cecere et al. 2014; Hasan et al. 2017). Watson et al. (2010, p. 24) illustrate this potential, for example, by stating that IS is helpful in "analyzing, designing, and implementing systems to increase the efficiency of energy demand and supply systems. This requires collection and analysis of energy data sets to support optimization of energy distribution and consumption networks." With reference to this potential of IS for environmental sustainability, various calls for new research were published to develop more insights into the usage of IS to facilitate environmental sustainability (Elliot and Webster 2017; Gholami et al. 2016; Malhotra et al. 2013). Melville (2010) also supports this claim and develops a research agenda with focus on IS-related environmental innovation, which we will define as green IS innovation in the following. To structure research in this context, Elliot (2011) provides a framework for IS-enabled

business transformation towards environmental sustainability and points inter alia to individuals and groups in organizations as one research avenue. We follow this research avenue from an upper echelon perspective and focus on the top management team (TMT) of firms. As members of the TMTs in firms are defined as the policy-making officers (Nath and Bharadwaj 2020), we argue that it is worth investigating the role of IS-related human capital of TMT members in facilitating green IS innovations. We base our argumentation on the claim that IS executives and the alignment with their colleagues in the upper echelons matter to explore the potential of IS for environmental sustainability (Benitez-Amado and Walczuch 2012; Loeser et al. 2017), but there are knowing-doing gaps in organization to successfully adapt IS for green IS innovations (Jenkin et al. 2011). Following this argumentation, we argue that IS-related human capital, in the form of IS-related education and IS-related experience of TMT members, fills this gaps and is positively associated with green IS innovation activities in firms. Further, we extend our research from the upper echelon perspective by following Bendig et al. (2023) and argue that attention for IS grows with the presence of CIOs in TMTs in firms (Fu et al. 2020; Lee 2021). Again by following this argumentation, we additional argue that the presence of CIOs in TMTs increases attention for IS as a solution to environmental sustainability challenges and that, consequently, the presence of a CIO positively moderates the positive association of IS-related human capital with green IS innovation activities.

To conduct the outlined research, we draw on a panel data set of firms listed in the Standard & Poor's 500 index (S&P 500) from 2010 to 2019. Using this data set, including patent data and various information on characteristics of TMT members, we conduct a fixed-effects negative binominal regression and show that IS-related human capital in the form of IS-related education and experience of TMT members is positively associated with green IS innovation activities. For our theorized role of CIOs, we find mixed results as we provide evidence for a positive moderation of the association between IS-related experience with green IS innovation activities but a significant negative moderation of the association between IS-related education with green IS innovation activities. With these results, we contribute to the IS literature in the intersection of the human capital theory and the attention based theory from an upper echelon perspective and the environmental sustainability literature. First, we contribute with new insights on the role of IS-related skills and capabilities in TMTs of firms as a lever to facilitate green IS innovations and strengthen the stated role of IS for environmental sustainability. With this focus, we secondly contribute to the human capital and attention based view by providing new insights on how specific human capital in upper echelons is associated with innovation activities of firms and how attention through the presence of specific policy making executive officers affect these innovation activities. And third, we provide a specific approach for the environmental sustainability literature to assess the required human capital to facilitate green (IS) innovations.

# Theoretical background and development of hypotheses

## *IS as an enabler of green innovations*

With the earth's average temperature already 1.1°C higher than in the pre-industrial era, the changing natural environment causes roughly 13 million deaths annually and costs developing nations about USD 70 billion to adapt (IPCC 2022; Neufeldt et al. 2021). To reverse this trend, corporations are essential in laying the foundation for environmental sustainability (Shrivastava 1995). A report by the Carbon Disclosure Project (CDP) emphasizes the importance of large corporations by demonstrating that since 1988, 100 large enterprises have been responsible for 71% of industrial carbon emissions, which are the primary cause of climate change (Griffin & Heede, 2017). Businesses must determine appropriate activities for a greener way of doing business while reducing carbon emissions in collaboration with politics (Burke et al. 2016). With reference to the described effects, this development is becoming increasingly demanded by society, resulting in increased awareness of corporate social responsibility (Arora et al. 2020) and environmental sustainability is also seen as a competitive advantage for firms (Bendig et al. 2022b; Matsumura et al. 2014; Orlitzky et al. 2011). Green innovations for sustainable operations and products, including relevant processes and infrastructures, are hereby seen as essential factors to enable the adaptation towards environmental sustainability (Burke et al. 2016). According to the International Organization for Standardization (ISO), such green innovations could be defined as the creation of technologies involved in saving energy, prevention of pollution, recycling of waste, sustainable design, and environmental management (Chen et al. 2006).

Existing research suggests that Information Systems (IS) can be crucial in facilitating environmentally sustainable business practices and green innovation (e.g. Cecere et al. 2014; Elliot 2011; Hasan et al. 2017). This potential is rooted in the belief that applying IS technologies can reduce negative environmental impacts to a greater extent than it causes (Hertel and Wiesent 2013). Following this argumentation, academic studies already show that IS already plays an important role, as many existent green innovations are linked to the advancements in the IS domain (Cecere et al. 2014). Researchers like Gholami et al. (2016, p. 522) further support the forward-looking importance of IS and state that even if IS could not solve all challenges related to climate change, "it is difficult to imagine solutions to environmental challenges without a substantial IS component in the future." IS's contribution to environmental sustainability is therefore not limited to the IS domain alone, but it can also play a role in reducing the negative impact of business activities outside the IS domain (Gholami et al. 2013). By supporting this broad role of IS for environmental sustainability, researchers argue that IS constitutes a change agent towards overall environmental sustainability in organizations (Bengtsson and Ågerfalk 2011), provide evidence that digital transformation improves the environmental performance of firms (Chen and Hao 2022), and state that IS could enable successful implementations of green strategies, (Benitez-Amado and Walczuch 2012). In addition, Melville (2010) argues that IS-related innovation for sustainable processes and practices is crucial for implementing an environmentally sustainable way of doing business. This broader application of IS to facilitate environmental sustainability, which we will refer to in this study, is also defined as green IS. In contrast to green IS, literature also provide the term green IT, whereby green IT focus on the reduction of the direct negative effect of the use, production and disposal of information technologies. Green IS as defined in literature also involves the positive effect of using IS on the overall environmental sustainability in organizations and thus, is not limited to the explicit IS domain (Gholami et al. 2013).

With reference to these insights into the potential of IS, calls for further research like “Spurring impactful research on information systems for environmental sustainability” (Malhotra et al. 2013) or “Information Systems Solutions for Environmental Sustainability: How Can We Do More?” (Gholami et al. 2016) were published. To answer this calls and develop more insights into the potential of IS to facilitate green innovation activities and environmental sustainability in firms, we refer to the framework of Elliot (2011) and focus on TMTs and their members. In the upcoming sections, we will pursue this focus and specifically address how IS-related human capital in TMTs and the presence of CIOs in TMTs affect the application of IS in green innovation initiatives to support environmental sustainability.

## *TMTs and (green IS) innovation activities*

The TMT is defined according to the Exchange Act as the team of "CEO and vice presidents in charge of a principal business unit, division or function and any other officer who performs a policy-making function," which by definition highlights the importance of the TMT for the innovation activities of firms (Daellenbach and George 1999; Nath and Bharadwaj 2020). With reference to these TMTs, the widely accepted and applied upper echelon theory from Hambrick (2007) claims that observable characteristics like age, education, and further experiences of members in the TMTs have a significant influence on the behavior and decision making in the upper echelons and thus, on the outcomes of their firms. Following this theory, wide-ranging studies are already published that analyze the relationship between characteristics of the TMT and innovation activities in firms (Menz 2012). Examples of innovation-related research referring to the upper echelon theory are TMT diversity (Talke et al. 2010), overconfidence in upper echelons (Hirshleifer et al. 2012), the presence of CTOs in TMTs of firms (Garms and Engelen 2019) and human capital quality (Chemmanur et al. 2019). With a focus on IS-related innovations, Firk et al. (2021) show that IS-related knowledge of TMT members is associated with an increase in IS-related innovation activities. Moreover, Bendig et al. (2023) provide insights that CIOs as part of the TMT increase the attention for IS-related topics, which in turn is associated with an increase in IS-related innovation activities. Also, studies with focus on the effect of TMT member characteristics on explicit green innovation activities are already published. Examples for results in this context are positive associations with green innovations of gender diversity (Galia et al. 2015; He and Jiang 2019), international experience (Zhang et al. 2023), and academic experience (He et al. 2021; Zhao et al. 2021). But until now, no explicit research on associations of IS-related characteristics of TMT members with green (IS) innovation activities are available.

## IS-related human capital in TMTs and its effect on green IS innovation

Scholars already claim that human capital plays a critical role in developing green innovations as they are more complex require a broader knowledge base than non-green innovations (Barbieri et al. 2020; Cainelli et al. 2015). As Jenkin et al. (2011) additionally identifies specific knowing-doing gaps when it comes to green IS initiatives in organizations, and Loeser et al. (2017) argues that IS will be leveraged if IS executives and their colleagues are aligned, we combine the human capital perspective with the potential of IS for green innovation to concentrate our research on the effect of IS-related human capital in TMTs on green IS innovations activities.

Human capital is defined by Becker (1962) as a person's accumulated knowledge, skills, and capabilities gained through investments in education and experience. In this context, Firk et al. (2021) and Choi et al. (2021) provide already evidence for the positive association of IS-related human capital in TMT members on IS-related innovations. Regarding green initiatives, Benitez-Amado and Walczuch (2012) additionally argue that IS capabilities in a firm enable proactive green strategies. Following these lines of argumentation, we argue that the IS-related human capital of TMT members is positively associated with green IS innovation activities in firms. To capture IS-related human capital in TMTs, we refer to Choi et al. (2021) and differentiate IS-related human capital between IS-related education and IS-related experience. First, we argue that TMT members who gained an IS-related education will tend to apply information systems to different challenges and consequently also to enhance green innovation activities. This argumentation is based on the assumption that TMT members with IS-related education have profound knowledge of the potential of IS and could evaluate more validly the chances of success of new applications of IS outside the IS domain (Banker et al. 2011; Choi et al. 2021; Tyler and Steensma 1998). We assume with this argumentation that the already proven relationship between IS-related human capital and IS-related digital innovations could be expanded to a broader role of IS in organizations, as suggested by Nambisan et al. (2017). Therefore, we theorize with reference to the previously outlined combination of the influence of TMT members on innovation activities and the potential of IS-related education for our first hypothesis:

> Hypothesis 1. IS-related education of TMT members is positively associated with green IS innovation activities in firms.

Second, we argue also, similar to our first hypothesis, that TMT members who gained an IS-related experience in their career will tend to apply IS to different challenges and consequently also to enhance green innovation activities. This argumentation is supported as TMT members with IS industry experience are superior in identifying application opportunities for IS (Custódio et al. 2019). Also, again similar to IS-related education, IS-related experience allows TMT members to explore application opportunities of IS (Colombo and Grilli 2005) and have greater confidence in the application of information technology (Choi et al. 2021). Following this argumentation in our context of green IS innovations activities, we theorize for our second hypothesis:

> Hypothesis 2. IS-related experience of TMT members is positively associated with green IS innovation activities in firms.

## The moderating effect of attention for IS through CIO presence in TMTs on green IS innovation activities

Besides the IS-related human capital of TMT members, we also refer to the presence of a dedicated CIO in the TMT to investigate potential associations from an upper echelon perspective with green IS innovation activities. For this investigation, we refer to the attention based view that claims that decision making outcomes in firms depend on the "noticing, encoding, interpreting, and focusing of time and effort by organizational decision-makers" (Ocasio 1997, p. 189). By additionally referring to the introduced definition of the TMT, we follow the argumentation that the TMT plays a central role in the distribution and allocation of attention in firms (Gavetti et al. 2012), which in turn influence the attention and resulting decision making in the whole organization (Brielmaier and Friesl 2023). Previous studies show hereby that the presence of specific functional officers is one factor to increase this attention inside and from the TMT, e.g. a chief human resource officer (Lee 2021) or a chief marketing officer (Umashankar et al. 2022). Thus, we argue that the presence of a CIO in the TMT channels the attention in the firm towards IS (Bendig et al. 2023). We expand this argumentation with the claim that this attention for IS also spreads to an application

of IS outside the explicit IS domain and consequently also in green innovation activities. Previous research shows that a CIO in a TMT has an influential role in developing and promoting IS-related solutions and products in firms (Benaroch and Chernobai 2017; Chen and W 2011). By combining the role of IS executives with environmental sustainability, Benitez-Amado and Walczuch (2012) support this line of argumentation and state that IS executives matter when it comes to shaping environmental sustainability. Loeser et al. (2017) argue additionally that IS executives should closely align their activities towards environmental sustainability to realize the potential of IS for green initiatives, which will be facilitated by a presence of a CIO in the TMT. Therefore, we expand our research and theorize that the presence of a CIO in the TMT will draw even more attention to the application of IS in green innovation and consequently positively moderate the hypothesized associations in hypotheses 1 and 2. Thus, we state further for hypotheses 3 and 4:

> Hypothesis 3. The presence of a CIO in the TMT positively moderates the positive association of IS-related education of TMT members with green IS innovation activities in firms.
>
> Hypothesis 4. The presence of a CIO in the TMT positively moderates the positive association of IS-related experience of TMT members with green IS innovation activities in firms.

Figure 1 summarizes our four hypotheses and shows our overall research model.

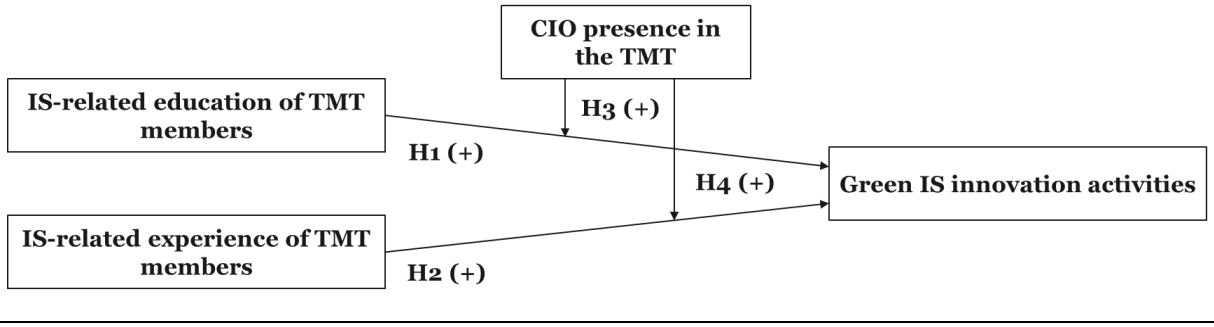


**Figure 1. Research model**

# Research design

## *Sample and data*

To test our hypotheses, we draw on a panel data set of firms listed in the S&P 500 index from 2010 to 2019. We focus our research on big corporates listed in the S&P 500 index, following the argumentation from Griffin and Heede (2017), who argues that these corporates are the main driver of the hazardous development of the natural environment. To measure the green IS innovation activities, we use patent data from the United States Patent and Trademark Office (USPTO) and retrieve the data from the publicly accessible platform Patentsview (Kim and Lee 2015; Savage et al. 2020; USPTO 2023). The provided data sets contain a technology classification according to the Cooperative Patent Classification (CPC), which allows a valid allocation of patents to IS-related and green and, consequently, to green IS innovations. Since innovation activities typically occur closer to the date of application than to the grant of a patent, we align our patent-related research to that date based on prior research (e.g. Chung et al. 2019). We also chose to confine our analysis to the years until 2019 to minimize the truncation bias resulting from a time lag between application and grant of patents (Trajtenberg 1990). To capture IS-related human capital, the presence of CIOs, and further characteristics of TMTs, we manually collected information from 10k reports and proxy statements filed according to requirements of the United States Security and Exchange Commission (SEC) (Nath and Bharadwaj 2020). To control for further effects on green IS innovation activities, we draw on data from Compustat for financial information and Refinitiv for ESG scores.

## *Measures*

Based on our retrieved data, we introduce different measures to test our hypotheses. We use patent data and related classification to build our dependent variable for all our hypotheses. We follow a similar

approach to Cecere et al. (2014) and draw on the fact that each patent could be allocated to more than one CPC class. We consequently measure green IS innovation activities by the count of patents that are allocated to green and IS-related CPC classes simultaneously. To identify green innovation activities, we hereby use the CPC class Y02 (Technologies or applications for mitigation or adaptation against climate change) (Bendig et al. 2022a; Su and Moaniba 2017). To identify the simultaneous IS-related classification, we refer to Vial (2019, p. 121) who conceptualizes IS-related technologies and consequently innovations as "information, computing, communication, and connectivity technologies". Following this conceptualization, we use the classes G06 (Computing; Calculating; Counting), G11 (Information Storage), G16 (Information and Communication Technology specially adapted for specific application fields), and Y04 (Information or Communication Technologies having an Impact on other Technology Areas) to identify IS-related innovations (Bendig et al. 2023).

| Variable | Methodological approach | Data source |
|---|---|---|
| Green IS innovation activities | Count of patents that are classified as IS-related and green simultaneously (based on Cecere et al. 2014) | USPTO |
| IS-related education of TMT members | Share of TMT members who studied an IS-related subject during their academic education (following Choi et al. 2021) | SEC filings (10k or proxy statement) |
| IS-related experience of TMT members | Share of TMT members who worked in an IS-related industry during their careers (based on Choi et al. 2021) | SEC filings (10k or proxy statement) |
| CIO presence in the TMT | Binary variable indicating CIO presence among the TMT members listed the firm's proxy statements (based on Bendig et al. 2022c) | SEC filings (10k or proxy statement) |
| Firm size | Logarithm of the number of employees per firm and year (based on Choi et al. 2021) | Compustat |
| Firm performance | Earnings before interest and taxes (EBIT) divided by total assets (following Choi et al. 2021) | Compustat |
| Capital intensity | Capital expenditure divided by total assets (based on Firk et al. 2021) | Compustat |
| Research & Development intensity | Research & development expenditure divided by total assets (based on Firk et al. 2021) | Compustat |
| Green orientation | Environmental pillar of the ESG score scaled down to a fractional variable (0-1) (following Zhai et al. 2022) | Refinitiv |
| IS industry transformation | Percentage change of the share of capital spending in IT-related investments (Benaroch and Chernobai 2017) | BEA |
| TMT size | Number of TMT members listed the firm's proxy statements (based on Firk et al. 2021) | SEC filings (10K or DEF 14A) |
| TMT tenure | Average number of years TMT members work in the current role (based on Firk et al. 2021) | SEC filings (10K or DEF 14A) |
| TMT experience diversity | Average of distinct SIC-industries in which TMT members worked (based on Crossland et al. 2014) | SEC filings (10K or DEF 14A) |
| TMT education diversity | Average of distinct areas of subjects that TMT members studied (based on Crossland et al. 2014) | SEC filings (10K or DEF 14A) |

**Table 1. Variable definitions and data sources**

To assess the IS-related human capital in the TMTs, we draw on manually collected information on the TMTs of S&P 500 corporates (Bendig et al. 2023). To collect these information, we scan the 10k or proxy statement which include short biographies including education and work experience for every TMT member of every corporate. If the 10k or proxy statement do not provide sufficient information, we also search for this information on corporate websites or social media profiles. To identify IS-related education, we evaluate every TMT member with a binary logic if the member studied an IS-related subject during their education (e.g. IT, Computer Science, Software Engineering) (Choi et al. 2021). We do the same for IS-related experience while we evaluate with a binary logic of the TMT member have work experience in IS-related industries, i.e. 357 (Computer and Office Equipment), 366 (Communications Equipment), 367 (Electronic Components and accessories), 48 (Communications), and 737 (Computer Programming, Data Processing, and other Computer Related Services)(Bendig et al. 2022c). To state if a CIO is present in the TMT and create the related binary moderator variable, we search for the titles "Chief Information Officer" or "Chief Digital Officer" in the list of TMT members (Bendig et al. 2022c). To account for further effects that potentially affect green IS innovation activities in firms, we also introduce firm size, firm performance, capital intensity, research & development intensity, green orientation, IS industry transformation, TMT size, TMT tenure, TMT education diversity, and TMT career diversity as control variables. Table 1 provides an overview of all introduced variables, including a short description of the methodological approach and the data source.

# Analysis and results

## *Analytical procedure*

Our data set includes ~5,200 firm-year observations with information on ~44,000 TMT members and ~550,000 patents. For this data set, we provide for all introduced variables descriptive statistics in table 2 and pairwise correlation in table 3. To assess the potential concern of multicollinearity, we additionally calculate the variance inflation factors (VIF) for all three planned regressions. With a mean VIF of 1.31 and a maximum VIF of 1.60, all values are well below the critical value of 10 (Petter et al. 2007). Therefore, we assume that multicollinearity is not a concern in our upcoming results. As our dependent variable, green IS innovation activities, constitutes a count variable and we can observe overdispersion for this variable in table 2 as the standard error exceeds the mean, we apply a negative binominal regression to test our hypotheses (Srivastava and Gnyawali 2011).

| Variables | Min | Mean | Max | S.D. |
|---|---|---|---|---|
| Green IS innovation activities | 0 | 2.08 | 251 | 13.29 |
| IS-related education of TMT member | 0 | 0.05 | 0.71 | 0.10 |
| IS-related experience of TMT member | 0 | 0.26 | 1 | 0.36 |
| CIO presence in the TMT | 0 | 0.21 | 1 | 0.41 |
| Firm size | 0 | 2.99 | 5.59 | 1.34 |
| Firm performance | -0.18 | 0.06 | 0.25 | 0.06 |
| Capital intensity | 0 | 0.04 | 0.26 | 0.42 |
| Research & Development intensity | 0 | 0.02 | 0.58 | 0.04 |
| Green orientation | 0 | 0.46 | 0.91 | 0.29 |
| IS transformation | -.053 | 0.00 | 0.03 | 0.01 |
| TMT size | 2 | 9.35 | 30 | 3.59 |
| TMT tenure | 1 | 14.81 | 41 | 6.46 |
| TMT experience diversity | 1.31 | 2.74 | 5 | 0.42 |
| TMT education diversity | 1.17 | 1.80 | 3.33 | 0.28 |

**Table 2. Descriptive statistics for introduced variables**

In addition, we follow the suggestion of a conducted Hausman test and use a fixed-effects model. To address potential reverse causality in all analyzed relationships, we lag the independent variable, the moderator, and all control variables by one year in all regressions. Additionally, we winzorized our control variables, firm size, firm performance, and R&D intensity at a 1 percent level to rule out the influence of extreme values. We would like to point out that the fixed-effect regression will reduce the observations due to the exclusion of all firms which do not develop any green innovation activities during the analyzed time window.

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) Green IS innovation activities | 1.00 | | | | | | | | | | | | |
| (2) IS-related education of TMT member | 0.29 | 1.00 | | | | | | | | | | | |
| (3) IS-related experience of TMT member | 0.26 | 0.46 | 1.00 | | | | | | | | | | |
| (4) CIO presence in the TMT | -0.04 | 0.03 | -0.09 | 1.00 | | | | | | | | | |
| (5) Firm size | 0.15 | 0.00 | 0.00 | 0.14 | 1.00 | | | | | | | | |
| (6) Firm performance | 0.10 | 0.07 | 0.12 | -0.01 | 0.09 | 1.00 | | | | | | | |
| (7) Capital intensity | 0.04 | -0.07 | -0.07 | -0.03 | -0.04 | 0.01 | 1.00 | | | | | | |
| (8) Research & Development intensity | 0.23 | 0.39 | 0.39 | -0.12 | -0.09 | 0.15 | -0.09 | 1.00 | | | | | |
| (9) Green orientation | 0.14 | 0.05 | -0.06 | -0.04 | 0.36 | 0.03 | 0.06 | 0.06 | 1.00 | | | | |
| (10) IS transformation | -0.04 | -0.03 | -0.04 | 0.02 | 0.00 | 0.00 | 0.06 | -0.03 | 0.00 | 1.00 | | | |
| (11) TMT size | 0.03 | -0.03 | -0.14 | 0.32 | 0.24 | -0.01 | -0.02 | -0.03 | 0.16 | -0.01 | 1.00 | | |
| (12) TMT tenure | 0.08 | -0.12 | -0.21 | 0.04 | 0.24 | 0.11 | 0.08 | -0.12 | 0.19 | 0.00 | 0.13 | 1.00 | |
| (13) TMT experience diversity | -0.05 | 0.04 | 0.22 | -0.04 | -0.07 | -0.01 | 0.06 | 0.00 | -0.03 | 0.03 | -0.17 | -0.41 | 1.00 |
| (14) TMT education diversity | 0.05 | 0.21 | 0.23 | -0.20 | -0.11 | 0.02 | -0.03 | 0.16 | -0.01 | 0.00 | -0.55 | -0.24 | 0.21 |

**Table 3. Pairwise correlations**

## *Results*

For each of our hypothesized relationships, we report results of a controls-only model, a model for the main relationship, and the full model, including the moderator. We show results for hypotheses 1 and 2 in table 4 and for hypotheses 3 and 4, as well as for the full model in table 5. Additionally, we provide margin plots for the effects of the theorized moderations in figures 2 and 3, respectively. Focusing on the results of the models, including independent and moderator variables, we observe in model 6 support for our hypotheses 1,2 and 2a, while we could not find evidence for our hypothesis 3. Thus, we provide evidence that IS-related education of TMT members ($\beta = 1.10$ and $p < 0.01$) and IS-related experience of TMT members ($\beta = 0.99$ and $p < 0.001$) are positively associated with green IS innovation in firms, while the association of IS-related education is positively moderated by the presence of a CIO in the TMT ($\beta = 2.06$ and $p < 0.001$). Our results in model 6 additionally show significant evidence for an opposite moderation as theorized in our hypothesis 3 ($\beta = -3.58$ and $p < 0.01$). In sum, our findings provide evidence for our theorized role of IS-related human capital in the TMT and, in part, for the presence of a CIO in the TMT for green IS innovations in firms.

| Variables | Model 1 (controls only) | Model 2 (main relationship H1) | Model 3 (main relationship H2) |
|---|---|---|---|
| *Independent variables* | | | |
| IS-related education of TMT mem. | | 1.32 (0.37) *** | |
| IS-related experience of TMT mem. | | | 1.18 (0.24) *** |
| *Control variables* | | | |
| Firm size | 0.22 (0.08) ** | 0.25 (0.08) ** | 0.32 (0.08) *** |
| Firm performance | 2.05 (0.66) ** | 1.93 (0.65) ** | 1.97 (0.61) ** |
| Capital intensity | -1.67 (2.06) | -1.52 (2.06) | -1.29 (1.87) |
| Research & Development intensity | 4.83 (1.34) *** | 4.36 (1.33) ** | 3.06 (1.41) * |
| Green orientation | -0.12 (0.29) | -0.17 (0.29) | -0.20 (0.28) |
| IS transformation | 0.08 (2.71) | 0.04 (2.64) | 0.20 (2.46) |
| TMT size | 0.02 (0.02) | 0.01 (0.02) | 0.02 (0.02) |
| TMT tenure | 0.02 (0.01) | 0.02 (0.01) † | 0.02 (0.01) † |
| TMT experience diversity | 0.25 (0.13) † | 0.21 (0.13) | 0.20 (0.13) |
| TMT education diversity | -0.07 (0.22) | -0.12 (0.22) | -0.02 (0.21) |
| | | | |
| Observations | 1,542 | 1,542 | 1,542 |
| Number of firms | 185 | 185 | 185 |
| Wald chi2 | 151.18 | 166.41 | 197.33 |
| Log-likelihood | -1916.19 | -1910.202 | -1904.76 |
| All independent and control variables lagged by one year; standard errors in parentheses<br>Significance levels: † p < .1; * p < .05; ** p < .01.; *** p < .001 | | | |

**Table 4. Results of fixed effect negative binominal regression for hypotheses 1 and 2 with green IS innovation activities as dependent variable**

| Variables | Model 4 (moderation H3) | Model 5 (moderation H4) | Model 6 (full model) |
|---|---|---|---|
| *Independent variables* | | | |
| IS-related education of TMT member | 1.43 (0.37) *** | | 1.10 ** |
| IS-related experience of TMT member | | 1.14 (0.24) *** | 0.99 *** |
| *Moderation* | | | |
| CIO presence in the TMT | 0.20 (1.17) | -0.33 (0.16) * | -0.04 |
| IS-related education of TMT member x CIO presence in the TMT | -2.46 (0.18) * | | -3.58 ** |
| IS-related experience of TMT member x CIO presence in the TMT | | 1.31 (0.58) * | 2.06 *** |

| | | | |
|---|---|---|---|
| *Control variables* | | | |
| Firm size | 0.25 (0.08) ** | 0.33 (0.08) *** | 0.33 *** |
| Firm performance | 1.98 (0.65) ** | 2.06 (0.62) *** | 2.12 *** |
| Capital intensity | -1.34 (2.05) | -0.94 (1.84) | -0.45 |
| Research & Development intensity | 3.99 (1.34) ** | 3.12 (1.42) * | 2.80 * |
| Green orientation | -0.10 (0.29) | -0.22 (0.28) | -0.16 |
| IS transformation | -0.11 (2.64) | 0.43 (2.44) | 0.04 |
| TMT size | 0.01 (0.02) | 0.02 (0.02) | 0.01 |
| TMT tenure | 0.02 (0.01) † | 0.02 (0.01) * | 0.02 * |
| TMT experience diversity | 0.24 (0.13) † | 0.22 (0.13) † | 0.25 * |
| TMT education diversity | -0.13 (0.22) | -0.03 (0.21) | -0.10 |
| | | | |
| Observations | 1,542 | 1,542 | 1,542 |
| Number of firms | 185 | 185 | 185 |
| Wald chi2 | 171.51 | 202.33 | 218.17 |
| Log-likelihood | -1907.38 | -1902.26 | -1894.08 |

All independent and control variables lagged by one year; standard errors in parentheses
Significance levels: † p < .1; * p < .05; ** p < .01.; *** p < .001

**Table 5. Results of fixed effect negative binominal regression for hypotheses 1, 2, 3, and 4 with green IS innovation activities as dependent variable**

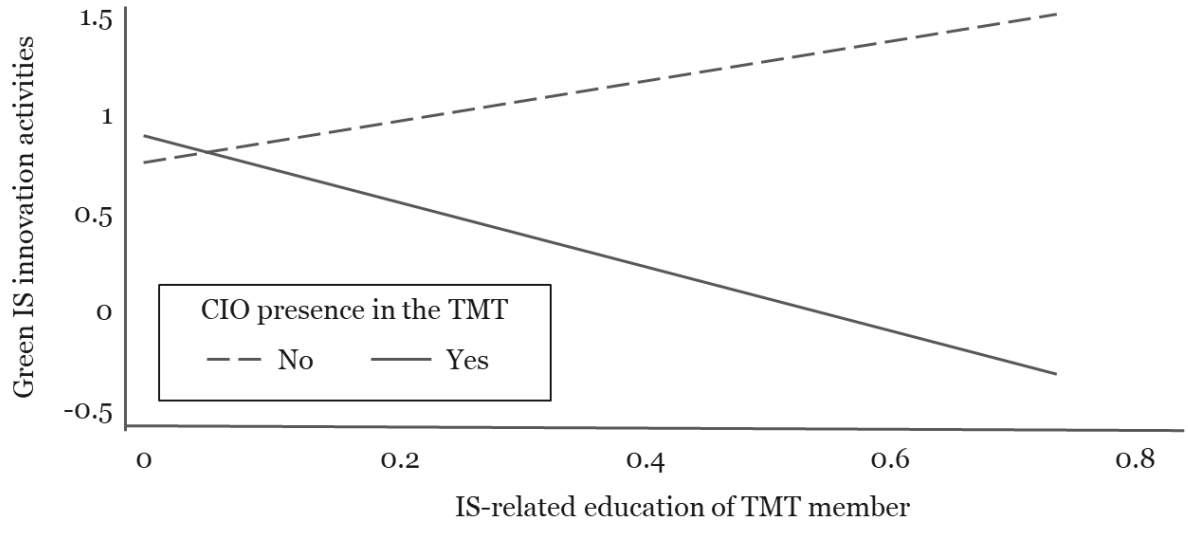


**Figure 2. Marginsplot for hypothesis 3**

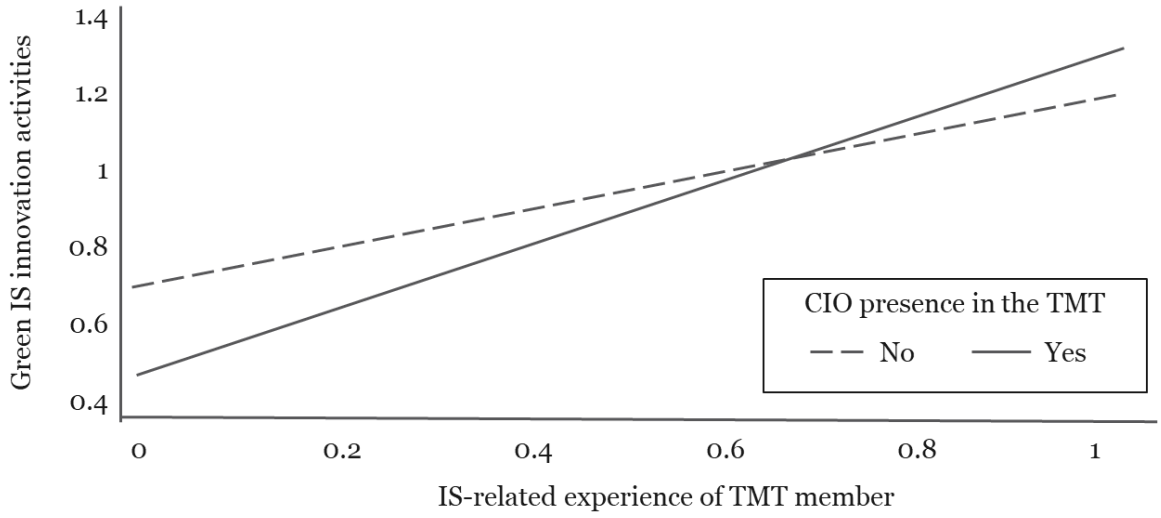


**Figure 3. Marginsplot for hypothesis 4**

### *Robustness and validity checks*

Despite a rigorous research design, we cannot infer that the insights from the previous section are fully robust. Therefore, we also conduct random effects regressions with industry fixed effects to ensure robustness. The results confirm the insights from our fixed-effects regression for hypothesis 1 ($\beta = 1.58$ and $p < 0.001$), hypothesis 2 ($\beta = 0.68$ and $p < 0.01$), hypothesis 3 ($\beta = -2.83$ and $p < 0.01$), and hypothesis 4 ($\beta = 1.38$ and $p < 0.01$).

To increase the validity of our research, we address endogeneity concerns in our research model by applying the two-stage predictor substitution (2SPS) approach, which constitutes an analog procedure to the popular two-stage least squares approach for non-linear regression models (Terza et al. 2008). To build our instrumental variable, we follow previous research and use an industry average of our two independent variables IS-related education of TMT members and the IS-related experience of TMT members (Attig et al. 2013; Germann et al. 2015). We back the usage of industry averages by arguing that the IS-related environment of firms will influence the composition of TMTs (e.g. Bendig et al. 2022c), but at the same time that industry averages should be exogenous to the individual decisions of firms. To assess the validity of our instruments, we can observe a significantly larger $R^2$ after including the instrument variables and significant relationships between the instrument and independent variables (Papies et al. 2017). The results of the 2SPS approach support our initial results for hypothesis 1 ($\beta = 2.77$ and $p < 0.05$), hypothesis 2 ($\beta = 1.10$ and $p < 0.01$), hypothesis 3 ($\beta = -7.06$ and $p < 0.01$), and hypothesis 4 ($\beta = 1.32$ and $p < 0.01$). We also address concerns regarding endogeneity in the form of a potential omitted variable bias, which could impact our results. As we apply a non-linear regression approach, we use the robustness of inference to replacement (RIR) approach from Frank et al. (2013). This approach provides a percentage metric to evaluate which proportion of the data sample has to be due to bias as they would have to be replaced with observation with an effect of zero. Following this approach, we find that to invalidate our results, a share of observations in our data sample of 35.10% (541 observations) for hypothesis 1, 76.76% (1184) for hypothesis 2, 80.85% (1259) for hypothesis 3, and 58.25% (898) for hypothesis 4 would have to be due to bias. Given our variable selection based on prior research and these values from the RIR approach in relation to our sample size, we infer that our results are not likely biased by omitted variables in our regressions.

## Discussion

### *Theoretical implications*

We develop our research by arguing that IS-related human capital in TMTs of firms is positively associated with green IS innovation activities, while the presence of a CIO in TMTs positively moderates these

associations. By providing empirical evidence for a positive association of IS-related education and experience with green IS innovation activities and for a positive moderation through CIO presence in TMTs of the association between IS-related experience with green IS innovation activities, we contribute to the IS literature at the intersection of the human capital theory and the attention based theory from an upper echelon perspective, and the environmental sustainability literature.

First, we contribute to IS literature by answering various calls for research on how IS can be operationalized to support the required development towards an environmentally sustainable way of doing business (e.g. Elliot and Webster 2017; Gholami et al. 2016; Malhotra et al. 2013). Elliot (2011) already claims that individuals and groups are one focus to support the implementation of IS in this way towards environmental sustainability. With focus on one of the most important groups in firms, we provide evidence that a high share of TMT members who are familiar with IS, either through education or experience, could constitute one lever for a successful adaptation of IS in the green innovation domain. By doing this, we expand the insights concerning the role of IS executives, for which Loeser et al. (2017) already claim that they play an important role in translating environmental strategies into green IS initiatives. We show in addition that not only IS-executives, but also IS-related skills and capabilities in the whole TMT are associated with increased green IS innovation activities. These insights additionally support the claim from Nambisan et al. (2017) for a shift of IS-related innovation activities from a narrow scope to a more open and inclusive innovation approach in a broader organizational setting. Second, we contribute from an upper echelon perspective to the human capital theory and the attention based theory. Various studies already investigate the role of specific human capital in TMTs firms' outcomes, e.g. Choi et al. (2021) for the positive moderation effect of IS-related education and experience on IS innovations. We further contribute to this literature stream and show that IS-related human capital, split into IS-related education and experience, is positively associated with green IS innovation activities. In addition, we provide new insights with reference to the attention based view Bendig et al. (2023) as we argue that the presence of a CIO in TMTs increases attention in firms to apply IS to environmental sustainability issues. For our hypothesis 3 which we cannot support with our analysis, we would like to discuss if a CIO, which is most likely a knowledgeable part of the TMT when it comes to IS-related topics, will rule out the positive effect of theoretical-driven IS-education of further TMT-members. This discussion would be in line with the claim that successful development and implementation of green innovations require a broad range of knowledge (e.g. Fusillo et al. 2020). In contrast, we argue that hypothesis 4 is supported as IS-related work experience is more practice oriented and thus, more compatible with a knowledgeable CIO in TMTs. Although, we find consequently mixed results in our study, which do not fully support our hypothesized role of attention through presence of a CIO in TMTs for green IS innovation activities, we enrich this literature stream with new insights on the role of a CIO for green IS innovation activities. With this focus, we thirdly contribute to the environmental sustainability literature. As research states that green innovations have higher requirements concerning human capital than non-green innovations (Barbieri et al. 2020; Cainelli et al. 2015), we provide a specific approach to evaluate the required human capital and with IS-related education and experience, consequently also new insights in which specific human capital could help to facilitate green (IS) innovations.

## *Practical implication*

Our research also provides relevant insights from a practical perspective. Following the IPCC (2022) report, businesses and the whole economy must take action to combat the hazardous development resulting from a changing ecological environment. Although business leaders know this threat, uncertainties about handling and responding to the challenge are seen as a significant hurdle (Elliot 2013). Our study helps practitioners as we offer insights into observable characteristics of TMT members, i.e. IS-related education and experience, which are associated with increased green IS activities. When appointing new TMT members, these criteria could be used to evaluate potential candidates. In addition, we shed light on the role of the CIO in leveraging the IS-related human capital in TMTs by bringing attention to the potential of IS for various challenges. As we could only find evidence for a positive moderation of IS-related experience with green IS innovation activities, our results could also be a starting point for discussions about why a CIO in TMTs apparently could not leverage IS-related education in TMTs in a similar way.

### *Limitations and future research*

We acknowledge that our study comes with limitations, which simultaneously offer the opportunity for future research. First, the usage of patents comes with a drawback as not all firms' innovation activities result in patent applications (Choi et al. 2021; Hall et al. 2005), and a second drawback results from patents' technologically and economically varying importance (Fabrizi et al. 2018). Future research could address these concerns by extending the innovation measurement to capture a broader range of IS-related innovation activities and to better evaluate the impact on the natural environment (Garcia-Granero et al. 2018). Second, the focus on IS-related education and experience allows a valid investigation of TMT member characteristics. Still, we can not entirely rule out further factors that affect the association between TMT members and green IS innovation activities (Choi et al. 2021). Further research could apply a varying research design, e.g. primary data sources such as interviews, to complement our insights. And third, although previous research already shows that organizational attention is generated by the presence of specific executive officers in the TMT, further factors can affect the influence of CIO presence on green IS innovation activities. Examples of such factors are the scope of responsibilities or the presence of IS executives on hierarchal levels below TMT as listed in the SEC filings (Bendig et al. 2023). As for our second limitation, also in this case, an adapted research design could validate our results.

## Conclusion

Focusing on the challenges arising from the ongoing hazardous development in the natural environment, we provide new insights on how IS-related human capital, in the form of IS-related education and experience, can constitute antecedents for green IS innovation activities. With these insights, we advance academic understanding of the operationalization of IS in combination with specific human capital from an upper echelon perspective to fulfill the complex requirements to progress towards environmental sustainability. Additionally, we investigated the role of attention in the form of a CIO presence in the TMT for IS-related solutions in the context of green innovations and built a basis for further discussions concerning the role of CIOs. Overall, we further anchor IS with our findings as a solution in the existing tool kit for combating the negative changes in the natural environment.

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