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Article

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Green innovation influenced by employee innovative work behavior via moderating role of innovative leaderships

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ABSTRACT

This study examines the dynamics of digital and green innovation within organizational contexts, focusing on the interplay between innovative work behavior, innovative leadership and the adoption of digital technologies. Survey data were collected from employees working in private sector organizations in Saudi Arabia, using a questionnaire encompassing key constructs related to digital and green innovation. Data analysis was conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM), revealing significant relationships between the variables under investigation. The results indicate that innovative work behavior positively influences digital innovation, while digital innovation in turn facilitates green innovation. Innovative leadership emerges as a critical factor influencing both digital and green innovation, with strong positive associations found between innovative leadership and innovation outcomes. Furthermore, the study underscores the importance of fostering a culture of innovation and investing in leadership development to drive both digital and green innovation effectively. The implications of these findings extend to organizations, policymakers and researchers, highlighting the importance of promoting innovation and sustainability initiatives in organizational and societal contexts. This study contributes to the understanding of the drivers of digital and green innovation, offering insights for organizations seeking to enhance their competitiveness and promote environmental sustainability in an increasingly digitalized world.

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1. Introduction

In the 21st century, the dynamic and evolving landscape underscores the necessity for organizations to cultivate network capabilities and foster innovative work behavior (IWB) (Nasaj & Badi, 2021). Innovation is widely acknowledged as a fundamental activity within manufacturing processes and organizational growth, playing a pivotal role in enhancing workforce productivity (Vivona et al., 2020). Recent scholarly attention has increasingly focused on innovation, with ongoing research efforts dedicated to exploring its various dimensions. Scholars endeavor to establish connections between individuals' engagement in innovation and several business facets, encompassing the evaluation of both the quantity and quality of their relational interactions. IWB stands as a critical element enabling organizations to maintain a competitive edge, thus ensuring their resilience and longevity in the rapidly changing digital era (Prieto & Pérez-Santana, 2014). IWB is intricately linked to organizational growth, expansion and the realization of novel and valuable ideas within enterprises. Consequently, sectors worldwide are prioritizing the promotion of innovative work practices among employees (Leong & Rasli, 2014). Previous research highlights numerous factors that influence the expansion and cultivation of IWB within the private sector, encompassing management styles, technology utilization, mentoring programs, among others (De Jong & Den Hartog, 2008; Koednok & Sungsanit, 2018).

Innovative individuals are renowned for their ability to think 'outside the box' and exhibit a strong inclination toward diverging from conventional approaches. While innovation in general has garnered

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considerable attention, the specific realm of green innovation, including sustainable innovation and environmental innovation, is gaining increasing prominence in both academic and practical spheres (Yang et al., 2024). Green innovation involves the development and implementation of new products, processes, or technologies that aim to minimize environmental impact or promote sustainability (Tang et al., 2023; Xu et al., 2024). Sustainable innovation, on the other hand, focuses on creating value for society and the environment while simultaneously driving economic growth (Schiederig et al., 2012). Similarly, environmental innovation refers to the introduction of new or significantly improved products, processes, organizational methods and marketing strategies that contribute to reducing environmental impact (Sharif et al., 2023). The pervasive influence of digital innovation is evident across nearly all sectors (Alateeg & Alhammadi, 2023, 2024). Specifically within the energy sector, digital innovation offers avenues for transitioning to new energy sources, harnessing untapped resources and optimizing energy consumption through intelligent solutions (Al-Ayed, 2024; Al-Ayed et al., 2023). In essence, digital innovation entails the adoption of advanced technologies aimed at enhancing workforce productivity and propelling the energy sector toward cleaner and greener production practices (Hao et al., 2023). Past research has delved into various determinants of IWB within the energy sector, including leadership behaviors (Wilson & Tyfield, 2018), cultural intelligence (Rao Jada et al., 2019), team learning behaviors (Widmann et al., 2016), and employees' dynamic capabilities (Montani et al., 2020). However, this study seeks to broaden the understanding of critical elements conducive to IWB within digital environments, suggesting that conventional antecedents alone may not fully capture the complexities of fostering innovation in the digital era.

Organizational innovation is a well-acknowledged driver of success (Alateeg et al., 2024), with IWB recognized as a fundamental catalyst. However, a specific understanding of how IWB influences digital innovation remains underexplored. This study delves into this gap, aiming to elucidate the nuanced ways in which employees' innovative initiatives contribute to the unfolding digital transformations within organizational contexts. Simultaneously, as businesses increasingly integrate digital technologies into their operations, the potential positive influence of these innovations on green practices raises crucial questions. The research endeavors to contribute to discourse, examining how digital innovation may serve as a catalyst for environmentally sustainable practices within organizations. The intricate dynamics between IWB and green innovation introduce another layer of complexity. This study examines the role of digital innovation as a mediator in this relationship, offering insights into the mechanisms through which IWB may influence and shape green innovation practices. Recognizing the pivotal role of leadership in organizational dynamics, this study further examines innovative leadership as a moderating factor in the relationships proposed. Innovative leadership plays a crucial role in shaping organizational culture, fostering a climate conducive to creativity and innovation, and ultimately driving organizational performance (Zhang & Bartol, 2010). In the specific context of green innovation, where organizations seek to develop and implement environmentally sustainable practices, the role of leadership becomes even more significant. Existing literature underscores the importance of innovative leadership in shaping organizational culture and strategy, yet a comprehensive exploration of its moderating role in the context of employee-driven innovation, digital innovation and green innovation is lacking. Through this comprehensive exploration, the research aims to provide a nuanced understanding of the interconnected dimensions of employee-driven innovation, digital innovation and green innovation, while also shedding light on the moderating influence of innovative leadership. The study's research questions are as follow.

- How does employee IWB influence digital innovation within organizations?
- What is the impact of digital innovation on green innovation within organizations?
- How does innovative leadership moderate the relationships between innovative work behavior, digital innovation and green innovation within organizations?

This study contributes to the existing literature in several ways. Firstly, it extends the understanding of the relationship between IWB and digital innovation within organizational contexts, shedding light on the mechanisms through which employee-driven innovation contributes to digital transformation. Secondly, by examining the impact of digital innovation on the adoption of environmentally sustainable practices, the study provides insights into the potential role of digital technologies in advancing

organizational sustainability efforts. Finally, by investigating the moderating role of innovative leadership, the study offers a nuanced understanding of how leadership behaviors influence the dynamics between IWB, digital innovation and green innovation, contributing both theoretically and practically to the evolving landscape of organizational innovation and sustainability.

The research is structured into several concise sections for clarity and coherence. It begins with an introduction that outlines the research gap and rationale for the study's objectives. Following this, the conceptual framework and hypotheses are introduced to provide a theoretical foundation. The methodology section details the research design and data analysis methods employed. Subsequently, the results are presented using structural equation modeling to elucidate key findings. Finally, the conclusion synthesizes the findings, discusses their implications, and suggests potential avenues for future research.

2. Theoretical underpinning

The integration of organizational creativity theory and organizational identity theory provide valuable frameworks for understanding the dynamics between innovative work behavior, digital innovation, innovative leadership and green innovation within organizations. Organizational creativity theory posits that creativity and innovation thrive in environments that encourage experimentation, risk-taking and the generation of novel ideas (Amabile, 1988). Within this framework, IWB emerges as a key driver of organizational creativity, as individuals contribute their unique perspectives and insights to the innovation process (Shalley et al., 2004). Organizational identity theory, on the other hand, emphasizes the importance of shared beliefs and values in shaping organizational behavior and decision-making (Albert & Whetten, 1985). When sustainability becomes embedded in the organizational identity, it guides employee actions and fosters a collective commitment to environmental stewardship (Chen, 2011). Digital innovation, enabled by advanced technologies and digital capabilities, plays a transformative role in driving organizational change and fostering creativity (Bharadwaj et al., 2013). Leveraging digital tools and platforms, organizations can streamline processes, gather and analyze data more effectively, and collaborate across teams and departments to generate innovative solutions to environmental challenges (Lian et al., 2022). Innovative leadership, characterized by visionary thinking, empowerment and a willingness to embrace change, is essential for creating an environment that nurtures creativity and innovation (Zhang & Bartol, 2010). Innovative leaders inspire and motivate employees to think differently, experiment with new ideas and push the boundaries of what is possible, thereby catalyzing green innovation efforts within the organization (Chen, 2011). Green innovation, defined as the development and implementation of environmentally sustainable products, processes, or business models, is shaped by the interplay of organizational creativity and identity (Sarkis et al., 2021). When organizations foster a culture of innovation, rooted in a strong sense of identity that values sustainability, it encourages employees to explore creative solutions to environmental challenges (Chen, 2011). By leveraging digital technologies and innovative leadership practices, organizations can further enhance their capacity for green innovation, driving positive environmental outcomes and contributing to a more sustainable future. Thus, organizational creativity theory and organizational identity theory provide valuable insights into the complex relationships between IWB, digital innovation, innovative leadership and green innovation within organizations. By understanding and leveraging these theoretical frameworks, organizations can create environments that foster creativity, embrace sustainability and drive meaningful innovation toward a greener future.

2.1. Innovative work behavior

IWB refers to the tendency of individuals within an organization to engage in activities aimed at generating and implementing novel ideas, processes, or products (De Jong & Den Hartog, 2008). It encompasses behaviors such as idea generation, experimentation, problem-solving and risk-taking. Innovative work behavior is crucial for organizational success as it fosters creativity, adaptability and competitiveness (Odugbesan et al., 2023). Employees who exhibit high levels of innovative work behavior contribute to the organization's ability to adapt to change, seize opportunities and maintain a competitive edge in dynamic environments (Jong, 2007). Encouraging and nurturing innovative work behavior among employees is therefore a key focus for organizations seeking to foster innovation and drive growth. IWB

and digital innovation are closely intertwined concepts within organizational contexts (Binsaeed et al., 2023). IWB refers to the propensity of individuals to engage in activities aimed at generating and implementing novel ideas, processes, or products. It encompasses behaviors such as creativity, experimentation and problem-solving. On the other hand, digital innovation involves the adoption and utilization of digital technologies to develop new products, services, or processes that enhance organizational efficiency, productivity and competitiveness (Shen et al., 2022). Thus, this study proposes the following hypothesis:

H1: There is a significant positive influence of IWB on digital innovation

2.2. Digital innovation

Digital innovation means using new digital technologies to solve business problems, make things better for customers and come up with new ways of doing business (Shen et al., 2022). These innovations are developed in response to prevalent issues across various domains of activity (Chatterjee et al., 2023). The influence of digital innovation on green innovation refers to the impact of contemporary digital technologies on the development and adoption of environmentally sustainable practices, processes and products (Tang et al., 2023). As organizations embrace digital innovation, they may leverage digital technologies to enhance their environmental performance, reduce resource consumption and minimize their ecological footprint. Digital solutions such as Internet of Things (IoT), big data analytics and artificial intelligence can enable organizations to optimize energy usage, improve waste management processes and develop eco-friendly products (Alahmad et al., 2021; Li et al., 2023). Additionally, digital platforms can facilitate collaboration and knowledge-sharing among stakeholders to promote sustainable practices across supply chains and industries (Xu et al., 2024). Hence, digital innovation plays a pivotal role in driving green innovation by providing organizations with the tools and capabilities to address environmental challenges effectively. Thus, this study proposes the following hypothesis:

H2: There is a significant positive influence of digital innovation on green innovation.

2.3. Innovative leadership

Innovative leadership is instrumental in fostering innovation within the organization, as senior managers actively promote its importance and exhibit a keen interest in developing strategies and plans tailored to innovation initiatives (Bel, 2010; Djordjevic et al., 2020). Additionally, leadership ensures that improvement plans are informed by feedback, reflecting a responsive and iterative approach to innovation (Oke et al., 2009). Moreover, the organization's commitment to innovation is embedded in its values, which are clearly articulated through objectives, principles and actions, underscoring the leadership's role in shaping the organization's strategic direction and operational framework with innovation as a central focus (Cortes & Herrmann, 2021). Together, these aspects highlight the proactive leadership stance toward driving innovation and emphasize its integral role in fostering a culture of innovation within the organization (Hughes et al., 2018).

As a moderator, innovative leadership interacts with the relationship between IWB and green innovation, shaping the strength or direction of this relationship. Innovative leaders play a pivotal role in creating an organizational climate that fosters creativity, experimentation and risk-taking, all of which are essential for driving green innovation initiatives (Şen & Eren, 2012). By championing environmental sustainability as a strategic priority, innovative leaders inspire and empower employees to engage in innovative behaviors that contribute to green innovation efforts (Blagoev & Yordanova, 2015). Moreover, innovative leadership influences the implementation and effectiveness of green innovation strategies within organizations. Through their vision, communication and decision-making, innovative leaders set the tone for sustainability initiatives and provide the necessary support and resources for their successful execution (Paxton & Van Stralen, 2015). They create a culture of openness and collaboration, where

employees feel encouraged to share their ideas and experiment with new approaches to addressing environmental challenges (Khalili, 2017).

In the context of organizational dynamics, the role of leadership is pivotal in driving both digital and green innovation (Dargan & Shucksmith, 2008; Vaccaro et al., 2012). A supportive and visionary leadership is expected to foster a culture conducive to innovation, encouraging employees to engage in innovative work behavior and facilitating the adoption of digital technologies for innovation purposes. This supportive leadership style is anticipated to positively influence the organization's digital and green innovation initiatives, leading to the development of novel solutions, practices and products (Hoch, 2013). Moreover, the effectiveness of innovative work behavior and digital innovation in driving innovation outcomes is contingent upon the leadership's involvement and support. Strong leadership may provide the necessary resources, direction and encouragement to translate innovative ideas into tangible innovation outcomes, thereby amplifying their impact. Conversely, ineffective leadership may impede the realization of innovation potential, hindering the organization's ability to capitalize on innovative work behavior and digital innovation for achieving meaningful innovation outcomes (Arici & Uysal, 2022). Thus, this study proposes the following hypotheses:

H3: There is a significant positive influence of innovative leadership on digital innovation

H4: Innovative leadership moderates the relationship between IWB and digital innovation.

H5: There is a significant positive influence of innovative leadership on green innovation

H6: Innovative leadership moderates the relationship between digital innovation and green innovation.

2.4. Digital innovation as a mediator

In organizational contexts, digital innovation serves as a mediator between IWB and green innovation (Shen et al., 2022). This suggests that the impact of innovative work behavior on green innovation outcomes is mediated or facilitated through digital innovation initiatives within the organization. Innovative work behavior, characterized by creativity, experimentation and problem-solving, drives the generation of novel ideas and solutions aimed at addressing environmental challenges and promoting sustainability (Tsou & Chen, 2023). However, the translation of these innovative ideas into tangible green innovation outcomes often requires the adoption and utilization of digital technologies. Digital innovation acts as a conduit through which innovative ideas generated through IWB are transformed into practical solutions and practices that contribute to green innovation efforts.

As a mediator, digital innovation operates as an intermediate mechanism through which the effects of IWB on green innovation are transmitted. Digital innovation encompasses the adoption and utilization of advanced technologies and digital platforms to drive organizational change and enhance efficiency (Bharadwaj et al., 2013). Within the context of green innovation, digital technologies play a transformative role in enabling organizations to develop and implement environmentally sustainable practices (Ylijoki et al., 2018). Employee innovative work behavior, characterized by proactive and creative actions, stimulates the generation of new ideas and solutions to environmental challenges (Kohli & Melville, 2019). Digital innovation acts as a catalyst for translating these innovative ideas into actionable initiatives that contribute to green innovation efforts. For instance, digital technologies enable organizations to optimize resource management, gather and analyze environmental data and collaborate across teams and departments to develop innovative solutions to sustainability issues (Felicetti et al., 2024).

New technologies like IoT, big data and AI help companies use resources wisely, save energy, and create sustainable products and services (Di Vaio et al., 2021). By leveraging digital innovation, organizations can effectively implement green initiatives, reduce environmental impact and achieve sustainability goals (Tang et al., 2023). Overall, the mediation role of digital innovation highlights its importance in facilitating the translation of innovative work behavior into tangible green innovation outcomes within

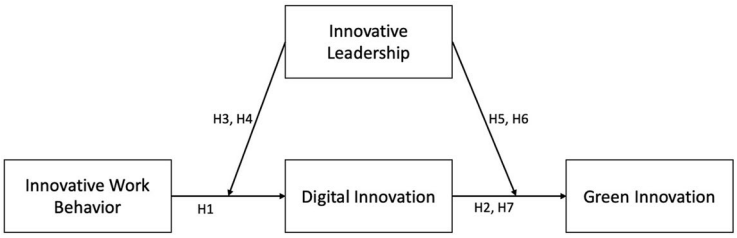

Figure 1. Research model.

organizational contexts (Aftab et al., 2022; Noor et al., 2023). It underscores the interconnectedness of innovative work behavior, digital innovation and green innovation, emphasizing the need for organizations to embrace digital technologies as enablers of sustainability and environmental stewardship. Thus, this study proposes the following hypothesis:

H7: Digital innovation mediates the relationship between IWB and green innovation.

Figure 1 depicts the model based on the selected variables for this study.

3. Methodology

3.1. Data collection

In January 2024, a survey was conducted among 371 managerial-level employees from 13 private sector firms in Saudi Arabia, aiming to investigate perspectives and practices regarding green innovation. The focus on managerial-level positions offers insights into decision-making processes and influence within organizations, particularly in driving innovation and implementing sustainability initiatives. The inclusion of employees from diverse industries within the private sector enhances the representativeness of the sample and allows for a comprehensive understanding of green innovation practices across different organizational contexts. To mitigate common method bias associated with cross-sectional data and self-report measures, various strategies were employed, including designing questionnaire items (Appendix) to measure different constructs independently and assuring respondents of the confidentiality of their responses. While the specific method used to control for common method bias was not detailed, the study sought to ensure the integrity and reliability of the data collected. Participants rated their opinions on a five-point Likert scale, 1 for strongly disagree to 5 strongly agree. Informed consent was obtained in writing from all participants prior to their involvement in the study. Participants were provided with comprehensive information about the study's objectives, procedures, potential risks and benefits. They were also informed of their right to withdraw from the study at any point without any repercussions. Questionnaire items were translated into Arabic for clarity. A preliminary assessment with 30 employees validated the questionnaire's reliability, resulting in refinements. Th ethical approval for this study was granted from Arab Open University under number 58/23/AOU. Through convenience sampling, 371 responses were collected via an online questionnaire. The demographic composition of the study's participants (Table 1) reveals several key characteristics. Male respondents dominate the sample, comprising 66%, while females account for 34%. Age distribution shows a fairly even spread, with around 31% of participants aged below 25, 25% between 25 and 30, another 25% between 31 and 40, and 19% above 40 years old. Educationally, a significant majority hold Bachelor's Degrees (72%), followed by high school graduates or equivalent (18%), Master's Degree holders (8%) and a smaller fraction with Doctoral Degrees (2%). Experience levels vary, with 38% having less than 3 years, 18% having 3-5 years, 14% having 6–10 years, and 31% having over 10 years of experience. Geographically, a substantial majority work in the Central region (75%), while smaller percentages are dispersed across the Eastern (9%), Western (7%), Northern (5%) and Southern (4%) regions.

3.2. Measurement

The survey began with an introduction to clarify research objectives and provide instructions. Participants then provided personal information. The next section evaluated specific constructs. Four items from

Table 1. Demographic of participants (n = 371).

	Frequency	Percent
Gender		
Male	246	66%
Female	125	34%
Age		
Less than 25 years	116	31%
25-30	93	25%
31-40	93	25%
Above 40	69	19%
Education		
High School or equivalent	66	18%
Bachelor's Degree	267	72%
Master's Degree	30	8%
Doctoral Degree	8	2%
Experience		
Less than 3 year	141	38%
3-5 years	65	18%
6-10 years	51	14%
Above 10 years	114	31%
Workplace region		
Southern	16	4%
Northern	19	5%
Western	26	7%
Central	278	75%
Eastern	32	9%

Akhavan et al. (2015) and Janssen (2000) measured IWB, while innovative leadership was assessed using four items adapted from Djordjevic et al. (2020). For the measurement of digital innovation, we employed six items sourced from Khin and Ho (2018), Binsaeed et al. (2023) and Paladino (2007). The assessment of green innovation with three items adapted from Chang (2011), Utterback and Abernathy (1975) and Song and Yu (2018). Table 2 presents detailed breakdown of each construct and its corresponding items.

3.3. Data analysis techniques

Data analysis utilized PLS-SEM via SmartPLS 4, known for reliability in management and IT research (Avkiran & Ringle, 2018). PLS-SEM was chosen for its suitability in exploratory research, especially in the context of limited prior research on green innovation in the private sector of Saudi Arabia. Its flexibility in handling small sample sizes and non-normal data, ability to model complex relationships among latent variables, and practical advantages in ease of use and interpretation make it an ideal choice for this study. PLS-SEM captures variance in latent dimensions and integrates theories with data, aiding theoretical validation and exploring variable relationships (Henseler et al., 2009). Following Leguina's (2015) two-step strategy, the outer model assessed discriminant and convergent validity, and the inner model tested hypotheses. This approach, combined with PLS-SEM, ensures research validity and robustness (Heuer & Liñán, 2013; Hoyle, 1999).

4. Analysis

4.1. Measurement model

Table 2 presents reliability and validity statistics for key constructs in the study, including digital innovation, green innovation, IWB and innovative leadership. The loadings of all the items above 0.7 met the threshold. The internal consistency of each construct is assessed through Cronbach's alpha, with values ranging from 0.83 to 0.904, all surpassing the commonly accepted threshold of 0.7, indicating strong reliability in measuring the constructs. Additionally, composite reliability values, measuring the overall reliability accounting for shared variance and measurement error, exceed 0.9 for each construct, indicating excellent reliability. The constructs also demonstrate robust validity, as evidenced by average variance extracted (AVE) values ranging from 0.676 to 0.762, surpassing the acceptable threshold of 0.5. These results collectively affirm the high quality and reliability of the measurement model, instilling confidence in the study's ability to accurately capture and assess the intended concepts of digital innovation, green

Table 2. Measurement model.

Items and constructs	Loadings	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)
Digital Innovation		0.904	0.926	0.676
DI1: 'The quality of our digital solutions is superior compared to our competitors"	0.851			
DI2: 'The features of our digital solutions are superior compared to our competitors"	0.797			
DI3: 'The applications of our digital solutions are totally different from our competitors"	0.846			
DI4: 'Our digital solutions are different from our competitors' in terms of product platform'	0.855			
DI5: 'Our new digital solutions are minor improvements of existing products'	0.754			
DI6: 'Some of our digital solutions are new to the market at the time of launching'	0.829			
Green Innovation		0.83	0.898	0.746
GI1: 'The company chooses the materials of the product that produce the least amount of pollution for conducting the product development or design'	0.881			
GI2: 'The company uses the fewest amount of materials to comprise the product for conducting the product development or design'	0.835			
GI3: 'The company would circumspectly deliberate whether the product is easy to recycle, reuse and decompose for conducting the product development or design'	0.875			
Innovative Work Behavior		0.896	0.927	0.762
IWB1: 'I usually introduce small innovations into my practice'	0.851			
IWB2: 'I often develop new procedures to improve my everyday practice'	0.879			
IWB3: 'I often succeed in transforming my innovative ideas into practical solutions'	0.922			
IWB4: 'I often develop new solutions to solve problems'	0.836			
Innovative Leadership		0.872	0.913	0.724
LD1: 'Senior managers promote the importance of innovation in the company'	0.838			
LD2: 'Senior management is interested in the development of strategies and plans relating to innovation'	0.884			
LD3: 'Improvement plans developed by senior managers are based on the management of feedback'	0.803			
LD4: 'Values which are based on the innovation in our company are clearly expressed in form of objectives, principles and actions and represent the foundation of strategic planning'	0.875			

innovation, IWB and innovative leadership as specified threshold by Henseler et al. (2009). Table 3 displays the results of the Fornell-Larcker criterion assessing discriminant validity. It confirms distinctiveness among constructs, crucial for accurate interpretation of their relationships. The Fornell-Larcker criterion is chosen for assessing discriminant validity due to its simplicity and effectiveness in determining whether constructs in a structural equation model are distinct from one another (Henseler et al., 2009). The Heterotrait-Monotrait (HTMT) ratios presented in Table 4 demonstrate the discriminant validity among

Table 3. Discriminant validity (Fornell-Larcker criterion).

	Digital innovation	Green innovation	Innovative work behavior	Innovative leadership
Digital Innovation	0.822			
Green Innovation	0.784	0.864		
Innovative Work Behavior	0.576	0.509	0.873	
Innovative Leadership	0.807	0.726	0.551	0.851

Table 4. Heterotrait-Monotrait ratio.

	Digital innovation	Green innovation	Innovative work behavior	Innovative leadership
Digital Innovation				
Green Innovation	0.671			
Innovative Work Behavior	0.657	0.614		
Innovative Leadership	0.701	0.543	0.658	

Table 5. Path coefficients.

Paths	β	Std deviation	T statistics	p value	Results
Innovative Work Behavior -> Digital Innovation	0.179	0.08	2.23	0.026	H1 supported
Digital Innovation -> Green Innovation	0.57	0.116	4.936	0.000	H2 supported
Innovative Leadership -> Digital Innovation	0.674	0.076	8.884	0.000	H3 supported
Innovative Leadership x Innovative Work Behavior -> Digital Innovation	0.276	0.045	1.685	0.022	H4 supported
Innovative Leadership -> Green Innovation	0.275	0.129	2.125	0.034	H5 supported
Innovative Leadership x Digital Innovation -> Green Innovation	0.014	0.053	0.264	0.792	H6 not supported
Innovative Work Behavior -> Digital Innovation -> Green Innovation	0.102	0.051	2.02	0.043	H7 supported

the constructs under examination. Each cell in the table represents the HTMT ratio between two constructs, indicating the extent to which they are distinct from each other. A ratio below the threshold of 0.85 suggests that the constructs exhibit discriminant validity, meaning they measure different underlying concepts (Henseler et al., 2009).

4.2. Structural model

Table 5 displays path coefficients, standard deviations, T statistics, p values and results for the examined relationships. β=0.179 shows a positive relationship between innovative work behavior and digital innovation (t=2.23, p=0.026), supporting H1. β=0.57 indicates a strong positive relationship between digital innovation and green innovation (t=4.936, p=0.000), supporting H2. β=0.674 suggests a strong positive relationship between innovative leadership and digital innovation (t=8.884, p=0.000), supporting H3. β=0.276 shows a positive moderation effect of innovative leadership between innovative work behavior and digital innovation (t=1.685, p=0.022), supporting H4. β=0.275 indicates a positive relationship between innovative leadership and green innovation (t=2.125, p=0.034), supporting H5. β=0.014 suggests a negligible moderation effect of innovative leadership between digital innovation and green innovation (t=0.264, p=0.792), not supporting H6. β=0.102 indicates a positive mediation relationship of digital innovation between innovative work behavior and green innovation (t=2.02, p=0.043), supporting H7.

Figure 2 shows R-square values for digital innovation (0.684) and green innovation (0.640), indicating the percentage of variance explained by the independent variables. These high values suggest strong predictive power in understanding innovation outcomes as specified by Henseler et al. (2009). Table 6 displays f-square values, indicating the effect size of each exogenous variable and interaction term when removed from the model. Digital innovation and innovative leadership show medium effect sizes (0.314 and 0.435), while IWB demonstrates a small effect size (0.270). Interaction between innovative leadership and IWB has a medium effect size (0.325), whereas with digital innovation, it shows a very small effect size (0.001).

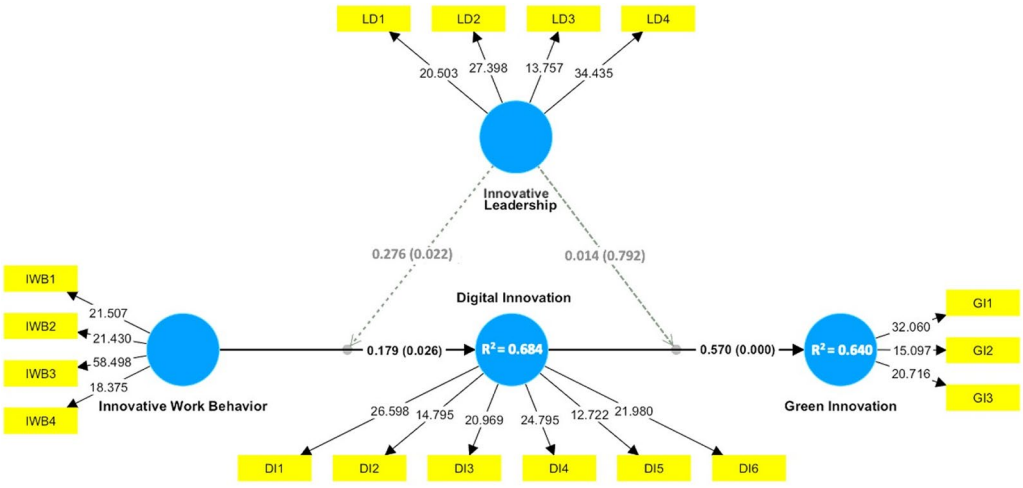

Figure 2. Model for green innovation.

Table 6. f-square.

	Digital innovation	Green innovation
Digital Innovation		0.314
Innovative Work Behavior	0.270	
Innovative Leadership	0.435	0.469
Innovative Leadership x Innovative Work Behavior	0.325	
Innovative Leadership x Digital Innovation		0.001

5. Discussion

The findings of this study shed light on the intricate dynamics driving digital and green innovation within organizational contexts, highlighting the crucial roles of innovative leadership, IWB and technological advancements. Firstly, the significant positive relationship between IWB and digital innovation underscores the importance of fostering a culture of creativity and initiative among employees. This emphasizes the need for organizations to encourage and support innovative thinking and actions among their workforce to drive digital advancements effectively (Odugbesan et al., 2023). Furthermore, the strong influence of digital innovation on green innovation emphasizes the potential for technological advancements to facilitate environmental sustainability initiatives. This suggests that organizations leveraging digital technologies may also find opportunities to enhance their environmental performance through innovation (Binsaeed et al., 2023; Djordjevic et al., 2020).

Innovative leadership emerges as a key factor influencing both digital and green innovation, with strong positive associations found between innovative leadership and both forms of innovation (Arici & Uysal, 2022; Hughes et al., 2018). Effective leadership plays a pivotal role in fostering innovation by providing direction, support and resources necessary for innovation initiatives to thrive. Additionally, the positive moderation effect of innovative leadership between IWB and digital innovation underscores the importance of a supportive leadership environment in fostering employee creativity and innovation (Shen et al., 2022; Xu et al., 2024). However, the lack of significant moderation impact of innovative leadership between digital innovation and green innovation suggests potential areas for further exploration. It may be that while leadership support is essential for driving digital innovation, additional factors specific to environmental sustainability may also play a significant role in influencing green innovation outcomes (Li et al., 2023).

Overall, the findings suggest that organizations aiming to promote digital and green innovation should focus on fostering a supportive organizational culture and leadership environment that encourages employee creativity and initiative, leverages digital technologies effectively and prioritizes environmental sustainability initiatives. By doing so, organizations can enhance their innovation capabilities and contribute to both digital transformation and environmental sustainability goals.

The study offers valuable insights for organizations, policymakers and researchers alike. Firstly, organizations stand to benefit from fostering a culture of innovation among their workforce, as evidenced by the positive correlation between IWB and digital innovation. This highlights the importance of encouraging employees to think creatively and take initiative, ultimately leading to the development of innovative digital solutions that can enhance organizational efficiency and competitiveness (Al-Ayed & Al-Tit, 2021). Additionally, the study underscores the pivotal role of effective leadership in driving both digital and green innovation (Arici & Uysal, 2022). Moreover, policymakers can leverage these findings to create incentives and policies that encourage organizations to invest in digital and green innovation (Al-Tit et al., 2022).

6. Theoretical implications

The theoretical implications of this study are multifaceted. Firstly, it contributes to the advancement of organizational creativity theory by elucidating the intricate interplay between IWB, digital innovation, innovative leadership and green innovation. By integrating these constructs within the framework of organizational creativity theory, this study offers insights into how creativity and innovation manifest in the context of environmental sustainability. Additionally, the study extends organizational identity theory by highlighting the significance of sustainability as a core component of organizational identity. By examining the moderation role of innovative leadership between IWB, digital innovation and green innovation, the study enriches our understanding of how identity shapes organizational responses to environmental challenges. Furthermore, by employing mediation and moderation models, the study provides a nuanced understanding of the mechanisms through which these variables interact to influence organizational outcomes, thereby advancing theoretical models of innovation and sustainability.

7. Managerial implications

On the managerial front, this study offers practical insights for organizations seeking to promote environmental sustainability and drive innovation. Firstly, organizations should prioritize the development of innovative leadership capabilities to foster a culture of creativity, experimentation and sustainability. Investing in leadership development programs that emphasize visionary thinking, empowerment, and adaptability can create an environment conducive to green innovation initiatives. Secondly, organizations should leverage digital technologies and platforms to enhance their green innovation capabilities. By investing in digital innovation initiatives that enable real-time monitoring, data-driven decision-making and collaboration, organizations can optimize their environmental performance and achieve greater sustainability. Thirdly, organizations should recognize and reward employee IWB that contributes to green innovation efforts. By creating incentives and recognition programs that encourage employees to generate and implement environmentally sustainable ideas, organizations can tap into the creative potential of their workforce and drive meaningful change toward sustainability. Lastly, organizations should integrate sustainability into their organizational identity and strategic priorities. By aligning organizational values, goals and practices with principles of environmental sustainability, organizations can foster a sense of purpose and commitment among employees, suppliers and stakeholders, driving collective action toward a greener future.

8. Conclusion

This study has provided valuable insights into the dynamics of digital and green innovation within organizational contexts. Through the examination of key constructs such as IWB, innovative leadership and the adoption of digital technologies, this research has highlighted the interconnectedness of these factors and their impact on innovation outcomes. The findings underscore the importance of fostering a culture of innovation and investing in leadership development to drive both digital and green innovation effectively. The results demonstrate that organizations can enhance their competitiveness and promote sustainability by encouraging employees to think creatively, take initiative, and leverage digital technologies to develop innovative solutions. Effective leadership plays a critical role in supporting and promoting innovation initiatives, providing direction,

support, and resources necessary for success. By understanding the dynamics of innovation and adopting strategies to foster a culture of innovation and leadership, organizations can position themselves for success in an increasingly competitive and environmentally conscious world. This study's limitations include reliance on cross-sectional data, neglect of external environmental factors, use of self-report measures, and focus on a specific context, limiting generalizability. Future research could explore external influences on green innovation, examine individual-level factors, adopt multi-level perspectives, and utilize qualitative methods to enhance understanding of green innovation processes.

Author contributions

Sura Al-Ayed assumes complete accountability for every facet of this study. I participated in conceptualization, design, data analysis, and interpretation. Furthermore, I contributed to drafting the manuscript, rigorously reviewing it for intellectual integrity, and granting final approval for its publication.

Ethical approval

We assure adherence to ethical and professional standards throughout the research process. Before participation, all subjects were given the necessary informed consent.

Disclosure statement

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Sura Al-Ayed is an Associate Professor of Business Administration who earned her Ph.D. from Jinan University in Lebanon and her MA in Business Administration from Al-Balqa Applied University. She is a qualified academic with extensive experience at the MBA level. Her research has been published in both national and international peer-reviewed journals, and she has served as a reviewer for various prestigious journals and studies in areas such as Total Quality Management, Human Resource Management, e-Government, and Leadership.

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Data availability statement

The data supporting the findings of this study are accessible from the corresponding author, Sura Al-Ayed, upon reasonable request.

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Appendix

Questionnaire

Items and constructs	Sources
Digital Innovation	Khin and Ho (2018), Binsaeed et al. (2023) and Paladino (2007)
DI1: 'The quality of our digital solutions is superior compared to our competitors"	
DI2: 'The features of our digital solutions are superior compared to our competitors"	
DI3: 'The applications of our digital solutions are totally different from our competitors"	
DI4: 'Our digital solutions are different from our competitors' in terms of product platform'	
DI5: 'Our new digital solutions are minor improvements of existing products'	
DI6: 'Some of our digital solutions are new to the market at the time of launching'	
Green Innovation	Chang (2011), Utterback and Abernathy (1975) and Song and Yu (2018)
GI1: 'The company chooses the materials of the product that produce the least amount of pollution for conducting the product development or design'	
GI2: 'The company uses the fewest amount of materials to comprise the product for conducting the product development or design'	
GI3: 'The company would circumspectly deliberate whether the product is easy to recycle, reuse, and decompose for conducting the product development or design'	
Innovative Work Behavior	Akhavan et al. (2015) and Janssen (2000)
IWB1: 'I usually introduce small innovations into my practice'	
IWB2: 'I often develop new procedures to improve my everyday practice'	
IWB3: 'I often succeed in transforming my innovative ideas into practical solutions'	
IWB4: 'I often develop new solutions to solve problems'	
Innovative Leadership	Djordjevic et al. (2020)
LD1: 'Senior managers promote the importance of innovation in the company'	
LD2: 'Senior management is interested in the development of strategies and plans relating to innovation'	
LD3: 'Improvement plans developed by senior managers are based on the management of feedback'	
LD4: 'Values which are based on the innovation in our company are clearly expressed in form of objectives, principles and actions and represent the foundation of strategic planning'	