Does training provision matter? Unravelling the impact of digital transformation on environmental sustainability

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Abstract

Purpose – Many firms are now pursuing large-scale change initiatives to accelerate their digital transformation (DT) and sustainable development. However, the success rate of DT projects is still low, and the extent to which DT enables firms to improve environmental sustainability (ES) remains unclear. Recently, researchers have argued that DT is more about people transformation rather than technology. Based on the contingent resource-based view, this study investigates how DT influences ES and examines the moderating role of training provision (TP).

Design/methodology/approach – Survey data gathered from manufacturers in China were analysed to test the proposed theoretical framework.

Findings – The results indicate that DT has a positive impact on ES, and that this effect is positively moderated by TP.

Practical implications – The empirical findings provide insights for managers to understand the success of digital sustainability transformation requires necessary digital knowledge and skills derived from TP.

Original/value – This study provides an initial examination of digital sustainability, which is a new stream of literature for the digital age, and further extends existing knowledge by demonstrating the importance of people (i.e., TP) in strengthening the effectiveness of DT on ES.

Keywords: digital transformation; environmental sustainability; training provision; digital sustainability; contingent resource-based view

Paper type: Research paper

1. Introduction

Environmental sustainability (ES), which entails eliminating harmful waste to protect the environment and conserve natural resources through more efficient and sustainable resource management (Ranjbari *et al.*, 2021; Roy *et al.*, 2020), has gained increasing recognition as a critical sustainability dimension, alongside economic and social considerations (Markman and Krause, 2016). Increasing environmental pressure, the depletion of natural resources, political imperatives, and eco-friendly consumers have placed major constraints on the traditional linear economy development , with pervasive impacts worldwide (Roy *et al.*, 2020). The Sustainability Report by the 26th United Nations Climate Change Conference (COP26) suggests that ES is of critical importance and considerable urgency (Ibrahim, 2022). The COVID-19 pandemic and lockdown highlighted the major footprint of conventional economic activities on the natural world, as the enforced economic standstill stimulated the rehabilitation of natural ecosystems (George and Schillebeeckx, 2022). Furthermore, the current energy security crisis caused by the Russia-Ukraine conflict has accelerated demands for a transition to net-zero (Samandari *et al.*, 2022).

At a firm level, pressure on profitability has positioned the economic dimension as the main consideration for sustainability efforts, which has often compromised ES (Green *et al.*, 2012). However, there are important synergies to be gained at the intersection of economic and environmental elements, and innovative organizations, who are able to identify positive synergies , have got the lion's share of sustainability (Liu *et al.*, 2018). Similarly, increasingly sophisticated markets and the new generations have put pressure on organizations to become more sustainable than ever, and only firms who recognise ES as a business priority, and internalise it into the company's strategy, have been able to provide environmental solution to successfully compete in the sustainability arena (Gualandris and Kalchschmidt, 2014).

The heightened importance of ES is particularly evident in the context of Industry 4.0. (George and Schillebeeckx, 2022). Digital transformation (DT) is one of the biggest challenges and opportunities facing businesses in today's digital age (Correani *et al.*, 2020; Li, 2022). In the era of Industry 4.0, digital technologies have dramatically reshaped industrial ecosystems, and many firms are pursuing large-scale initiatives to capture the benefits of adopting emerging technologies (Nasiri *et al.*, 2020; Yu *et al.*, 2021; 2023). The ongoing COVID-19 crisis has further forced firms worldwide to accelerate their DT, referring to transforming business processes and organizational management through the adoption of digital technologies to enable major business improvements (Nasiri *et al.*, 2020; Philip, 2021). DT benefits businesses by developing smart products and services that enhance customer experience, improving productivity and efficiency, and creating digital ecosystems (Correani *et al.*, 2020; Gong and Ribiere, 2021). However, not all DT projects deliver performance benefits, and the success rate is still low (Bughin *et al.*, 2019; Saarikko *et al*., 2020). Further empirical research is required to identify why.

Prior research has examined various antecedent factors influencing ES, including lean practices and innovativeness (Yu *et al.*, 2020), just-in-time and total quality management (Green *et al.*, 2019), as well as supply chain collaboration and communication (Jadhav *et al.*, 2019). More recently, the question of how to exploit ES with digital technologies has attracted considerable attention (Bohnsack *et al.*, 2022; Guandalini, 2022). As a complex task (Lennerfors *et al*., 2015), ES involves managing limited resources in a sustainable manner and eliminating waste from the manufacturing process to protect the environment and natural resources (Goodland, 1995; Roy *et al*., 2020), which can benefit from DT (Li, 2022; Li *et al.*, 2020). The digital sustainability area has emerged as a result, which refers to the implementation of sustainable practices by businesses, aiming to propel the achievement of sustainable development goals through innovative utilization of digital technologies that collect, interpret, analyse, and process data (George *et al*., 2021; George and Schillebeeckx, 2022), and is undisputedly poised to be one of the salient characteristics of current and future industrial development (George *et al*., 2021). However, it remains unclear how digitalization can assist sustainability (George and Schillebeeckx, 2022; Guandalini, 2022). According to the resource-based view (RBV), firm can achieve competitive advantages (e.g., environmental advantage) through synergizing valuable digital resources (Barney, 2001). We argue DT can be regarded as such valuable digital resource to achieve environmental advantage (ES). Thus, consistent with the RBV, we develop the first research question: *RQ1: How does DT improve ES?*

DT is also about people transformation (Frankiewicz and Chamorro-Premuzic, 2020). Recent research has even argued that successful DT needs to go beyond pure technologies to place more emphasis on human resource management (HRM) practices, such as soft skills and leadership, transformational leadership behaviours, and digital talent development, all of which are essential for DT success (Forth *et al*., 2020; Frankiewicz and Chamorro-Premuzic, 2020; Philip, 2021). Thus, DT depends on ensuring the right people with the right skills are allotted to the right roles within and across organizations and supply chains (Frankiewicz and Chamorro-Premuzic, 2020; Manfreda and Indihar Štemberger, 2019). The necessary knowledge and skills for DT success are often cultivated through employee training provision (TP), which refers to the provision of training and development programs for employees to improve their pertinent skills and knowledge (Huo and Boxall, 2018; Sterling and Boxall, 2013). These conditions suggest that the implementation of DT is a necessary resource for enabling firms to improve ES, but DT is not sufficient in itself; it requires TP. This argument is consistent with the contingent resource-based view (CRBV), which extends the RBV, to understand the role of complementary resources in the realization of competitive advantage (i.e., ES) (Brandon-Jones *et al*., 2014). As the question of how digitalization can support sustainability improvement remains open (Bohnsack *et al.*, 2022; George and Schillebeeckx, 2022; Guandalini, 2022), we believe TP is crucial to enhance ES, and thus complement how DT affects ES. Therefore, based on the CRBV, , we expect that the effect of DT on ES depends to some degree on the level of TP. We therefore offer *RQ2: How does TP moderate the DT–ES relationship?*

By addressing these two research questions our study contributes significantly to existing research and practice. First, the question "can digitalization create sustainability?" remains largely unanswered (George *et al*., 2021; George and Schillebeeckx, 2022; Guandalini, 2022). Against this backdrop, we adhere to the RBV to address RQ1, examining the impact of DT on ES. According to the RBV, successful DT, as a key firm resource, could drive sustainability performance and competitive advantage (Aragón-Correa and Sharma, 2003). Managerially, our study provides business leaders with timely and useful insights into the digitalization–sustainability convergence, given the increased pressure to be environmentally sustainable. Second, although previous research suggests that people and digitalization should coexist and collaborate for achieving DT success (Frankiewicz and Chamorro-Premuzic, 2020; Philip, 2021), the question of "how digitalization can create sustainability" also remains unanswered (Bohnsack *et al*., 2022). Extending the RBV, we use the CRBV to explore the moderating effect of TP on the DT–ES relationship. Conducting moderation analysis sheds new light on the underlying influential mechanisms of digitalization. From a practical perspective, the moderation finding provides managers with useful guidance on the development of the digital sustainability transformation process, which may explain why, and under which circumstances some firms obtain environmental benefits from digitalization while others do not.

2. Theoretical background, model, and research hypotheses

2.1. Theories: the RBV and CRBV

The RBV provides a theoretical argument to explain how a firm can achieve competitive advantages through synergizing resources (Barney, 2001). It asserts that resources, which can be categorized as valuable, rare, inimitable, and non-substitutable, can be employed for sustaining competitive advantage and achieving superior performance (Barney, 1991, 2001). While the RBV provides a theoretical lens to understand the different outcomes of possessing diverse resources, it is argued that the RBV is absent of conditional aspects of organisational resources (Barney, 2001; Priem and Butler, 2001). Specifically, the RBV suffers from context insensitivity, in the sense that it is unable to explain how some resources can create competitive value under certain conditions, while not being similarly instrumental in others (Ling-yee, 2007). Contingency theory suggests that firms must build the proper alignment of resources with unpredictable factors that are both intrinsic and extrinsic to organizations, in order to achieve the realizable effectiveness or outcomes of resource utilizations (Donaldson, 2001). Thus, some researchers extended the RBV to include a contingency perspective in the assessment of the competitive value of resources (Aragón-Correa and Sharma, 2003; Brandon-Jones *et al*., 2014).

The CRBV emerged as an extension of the RBV to understand the role of contingent variables or complementary resources in the realization of competitive advantages (Brandon-Jones *et al*., 2014). The CRBV underlines that the effectiveness of bundling resources is contingent upon the exogenous context or the linkages between the primary and complementary resources (Aragón-Correa and Sharma, 2003; Brandon-Jones *et al*., 2014; Sedera *et al*., 2016). Here, the delineation of primary or complementary resources is also context dependent. The CRBV provides this study with a useful theoretical lens through which to investigate the contingent conditions under which DT can produce greater sustainability value.

The CRBV is instrumental in understanding the competitive advantage derived from resources and capabilities, particularly in today's dynamic digital environment (Seyedghorban *et al.*, 2020). While previous studies indicate that DT has the promising potential to exert influences on value-adding activities (Nasiri *et al.*, 2020; Nayal *et al.*, 2022), little is known about how to maximize the sustainable returns to digital investments (Kane, 2016). In applying the CRBV, we attempt to explore how DT, as a primary organisational resource, drives competitive value in sustainability (i.e., ES). The previous literature has highlighted several contingency factors deemed essential for harnessing the full business value of DT, such as digital maturity, data analytics, and training provision (Zouari *et al.*, 2021; Colbert *et al.*, 2016). Notably, among these factors, TP emerges as a significant contextual element that influences the outcome of DT. Effective and appropriate training equips employees with the necessary skills and knowledge to adeptly utilize digital technologies, thereby enabling companies to maximize their digital investments and improve their competitiveness (Hautala-Kankaanpää, 2022).

According to the CRBV, the relationship between DT and its business value, often represented as ES, may vary across firms depending on their respective levels of TP. As the provision of trainings is increasingly significant in today's disruptive digital environment (Frankiewicz and Chamorro-Premuzic, 2020), we argue that DT is a necessary but insufficient resource for developing greater ES. In this study, we examine the proposition that TP serves as a complementary and enhancing resource to DT. When TP is sufficiently supported and encouraged, DT will realize maximum returns on digital investments by delivering on the promise of sustainability.

2.2. Theoretical constructs

2.2.1. DT

DT is defined as adopting digital technologies or developing new digital business models to update and improve business processes, customer experience, organizational aspects, and culture, which enable firms to establish and sustain competitive advantage (Nasiri *et al*., 2020; Philip, 2021). DT involves leveraging digital technologies to enable major business improvements, such as enhancing customer experience, developing new smart products and services, streamlining operations process, and creating new business models (Gong and Ribiere, 2021; Hess *et al*., 2016).

In recent years, DT has become a strategic imperative, driving fundamental changes to business processes and routines. Such activities include developing new digital business models and systems for new product and service development, market knowledge creation, and strengthening external integration with business partners such as customers and suppliers, as well as adopting digital technologies for collecting data and information about new markets, products, and technologies (e.g., Gong and Ribiere, 2021; Nasiri *et al*., 2020; Sedera *et al*., 2016). DT empowers firms to leverage their digital technologies to reconfigure their existing business activities and transform their business process, thereby enabling them to reinforce the value creation process and disclose new ways to generate value (Li, 2022; Verhoef *et al*., 2021).

2.2.2. ES

ES incorporates initiatives and efforts to manage limited resources in a more effective, efficient, and sustainable manner, and to reduce or eliminate the generation of harmful and persistent waste to protect the environment and natural resources (Goodland, 1995; Ranjbari *et al*., 2021; Roy *et al*., 2020). As the overall pressure on managing natural resources efficiently is increasing, firms are required to implement environmentally friendly practices, such as reducing uncontrolled waste disposal, use of hazardous substances, energy consumption, environmental accidents, polluting air emissions, and greenhouse gas emissions in general (particularly carbon dioxide and methane) (Dubey *et al*., 2019; Paulraj, 2011; Yu *et al*., 2020). ES was recognised during the COP26 to be an issue of critical importance and considerable urgency (Ibrahim, 2022).

Managing ES is becoming increasingly crucial for manufacturers around the world because of resource depletion, global warming and climate change, water scarcity, pollution, and poor waste management, all of which have become major global environmental issues that have direct impacts on the future possibilities of industrial activities, and which inspire increasingly stringent environmental regulations that impinge on conventional or legacy industrial activities (Paulraj, 2011; Roy *et al*., 2020). As a principal dimension of sustainability, ES has become a strategic imperative and integral part of business processes, which warrants the quest for satisfying human needs while not compromising the quality of the environment through preventing and reducing adverse environmental impacts (Feroz *et al*., 2021; Demartini *et al*., 2019).

Prior empirical studies have explored the antecedent determinants that impact ES, such as just-in-time and total quality management (e.g., Green *et al.*, 2019), green supply chain management practices (e.g., Feng *et al.*, 2018; Green *et al.*, 2019), lean practices and innovativeness (e.g., Yu *et al.*, 2020), and supply chain collaboration and communication (e.g., Jadhav *et al.*, 2019). In recent times, empirical works have also examined the impact of digital technologies on promoting ES (e.g., Li, 2022; Li *et al.*, 2020). Nevertheless, none have delved into ES from the HRM perspective, specifically, none have explored the moderating effect of TP on the relationship between DT and ES, as we did in this present study. Thus, our study makes a substantial contribution to the existing body of research by investigating the interplay between DT and HRM (i.e., TP), with a specific focus on the moderating effect of TP. Through empirical testing of the moderation model, our study provides crucial evidence that enhances the comprehension of how people and digitalization can harmoniously coexist and synergistically collaborate to foster sustainability.

2.2.3. TP

Training has been widely considered as one of the key aspects of HRM, especially in the digital age (Frankiewicz and Chamorro-Premuzic, 2020; Huo and Boxall, 2018; Marler *et al*., 2006). Providing training and development programmes for employees (such as technical, team skills, and customer service training) enables them to enhance their relevant skills and knowledge, increasing their satisfaction and their ability to perform optimally in their current and future roles within the organization (Campion *et al*., 1993; Huo and Boxall, 2018). In the context of Industry 4.0, the provision of necessary trainings can increase employee awareness of the benefits and challenges of implementing DT projects (e.g., how to use new digital technologies and shape employees' attitudes about the digital technologies) and equip employees with core digital skills and knowledge (e.g., how to collect, analyse and share data through digital platforms for making smart decisions and better understanding customer needs) (Frankiewicz and Chamorro-Premuzic, 2020; Marler *et al*., 2006).

Firms able to apply effective training programmes are better situated for learning and knowledge transfer, and can provide their employees with sharpened technical and interpersonal skills to accomplish desired organizational objectives more effectively; aside from increasing the actual operational value of employees (due to their improved knowledge and skill), TP increases employee satisfaction, loyalty, and commitment, thereby improving staff retention and reducing human resource turnover costs (Campion *et al*., 1993; Sterling and Boxall, 2013). Adequate TP promises to evoke employees' motivation to participate in problem-solving activities and reduce employees' resistance to change when new technologies or business models are introduced, thereby rendering organizations more flexible and adaptive, which increases their resilience and dynamism (Marler *et al*., 2006; Muduli *et al*., 2013).

2.3. Research model and hypotheses

Grounded in the RBV and CRBV, this study develops a research model that explores how digitalization improves sustainability, as displayed in Figure 1. The foundational thesis of this study is that DT is a necessary (as suggested by the RBV), but largely insufficient resource for enabling greater ES (as suggested by the CRBV). We therefore argue that the provision of trainings is an important complementary resource for firms that seek to use DT to strengthen their ES. First, based on the RBV, we investigate the direct effect of DT and ES, i.e., to identify whether DT, as an important primary resource, enables firms to improve their environmental performance (RQ1). Second, based on the CRBV, we explicate the complementary (moderating) effect of employment TP on the DT–ES relationship, i.e., to determine whether the effectiveness of DT on ES depends to some degree on the level of TP (RQ2).

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2.3.1. Impact of DT on ES

Derived from the RBV, DT is considered as a primary resource that empowers ES (Aragón-Correa and Sharma, 2003; Brandon-Jones *et al*., 2014). Despite the increasing attention given to the importance of DT in facilitating sustainability, the existing literature has primarily been conceptual (e.g., Cetindamar *et al.*, 2022; Guandalini, 2022; Koseleva and Ropaite, 2017; Kouhizadeh *et al.*, 2021), case-based (e.g., Demartini *et al.*, 2019), or focused solely on technological aspects (e.g., Tang *et al.*, 2022), which necessitates further empirical investigation.

Firms are increasingly dependent on deploying digital technologies, such as the Internet of Things (IoT), Big Data Analytics (BDA), and blockchain, for carrying out sustainable business practices that target energy efficiency, resource conservation, and the reduction of waste and hazardous materials and accidents (George and Schillebeeckx, 2022; Kunkel and Matthess, 2020). For example, IoT technologies enable firms to collect data about resources and waste on a timely basis, and integrate such data into their production schedules, which allows them to track and link waste and emissions to specific processes and enhance the conservation of natural resources (Felsberger and Reiner, 2020; Li, 2022).

Similarly, a blockchain-powered platform enables firms to monitor energy consumption and resource usage more accurately and continuously, and to share such information among network participants and stakeholders, which helps in identifying environmental issues in the manufacturing process (Kouhizadeh *et al*., 2021; Tang *et al*., 2022). Collecting and analysing big data enables firms to quantify environmental performance (e.g., CO2 footprint, and waste and toxic materials production), as well as to identify hidden patterns of energy consumption and waste generated, to promote resource conservation and energy efficiency (Cetindamar *et al*., 2022; Koseleva and Ropaite, 2017).

Overall, DT provides firms with digital solutions for environment problems through increasing the visibility of ecological footprints, energy consumption, waste production, and usage of hazardous materials (Guandalini, 2022; Ukko *et al*., 2019). DT enables firms to better understand the impacts of their operations on the natural environment (Idrees and Zheng, 2020), and to purposely develop effective environmental strategies to mitigate adverse impacts and improve ES (Demartini *et al*., 2019). Consistent with the RBV, the development of ES necessitates firms to manage their limited resources in the most efficient, effective, and sustainable way, which requires leveraging digital technologies to improve pollution control, waste management, and sustainable production (Feroz *et al*., 2021). We therefore propose that:

H1: DT is positively related to ES.

2.3.2. Moderating effect of TP

Previous research has argued that the success of DT implementation depends on talent, not just technology, and has suggested various success factors such as prioritizing people, emphasizing soft skills, and leadership (Frankiewicz and Chamorro-Premuzic, 2020; Philip, 2021). However, existing research has primarily been conceptual (e.g., Vial, 2019) and case-based (e.g., Dremel *et al.*, 2017), underscoring the need for further empirical research to examine the specific contingency role of TP. Therefore, extending the RBV, and in line with the CRBV, this study employs a contingency view of resources, and argues that the delivery of value by DT is contingent upon the adequate support of TP. Although digital resources can create business value (H1), the leveraging of digital technologies is more effective in engendering ES when DT and TP are synergistically combined (Brandon-Jones *et al*., 2014; Sedera *et al*., 2016).

It has been suggested that digital technologies, when properly internalized and combined with an adequately trained and qualified workforce (i.e., with commensurate technical skills and knowledge), can enable firms to optimize the benefits of DT (Frankiewicz and Chamorro-Premuzic, 2020; Marler *et al*., 2006). The effective implementation of sustainable practices often requires the adoption of novel digital technologies to improve sustainable business processes, which may cause fundamental changes in business models, routines, and organizational structures (Kunkel and Matthess, 2020; Feroz *et al*., 2021). However, employees tend to resist such changes when disruptive technologies are introduced (Kane, 2016; Marler *et al*., 2006), due to a lack of familiarity, understanding, and knowledge of digital technologies (Kamble *et al*., 2019).

Indeed, employees are generally demotivated to participate in sustainable technology-intensive projects and problem-solving activities due to a lack of understanding of the implications of new technologies, such as the fear of redundancy, the functionality of such solutions, and their potential implications for everyday operational activities (Vial, 2019). There is a need to provide employees with training programmes to improve their knowledge of digital technologies as well as their corresponding digital skills in order to be able to harness the advantages offered to them (as well as their organizations) by the deployment of digital technologies, such as to solve complex problems more effectively and reduce the tedium associated with some traditional tasks (Colbert *et al*., 2016).

ES improvement is also reliant on cross-functional cooperation among intra-organizational units to solve increasingly complex sustainable problems (Longoni and Cagliano, 2015), which especially emphasizes the role of IT functions to perform technology-based sustainable practices (Dremel *et al*., 2017; Vial, 2019). Adequate TP performs a potential role in reinforcing communication and employee interpersonal skills, which is instrumental in strengthening cross-functional linkages among different functional departments (Marler *et al*., 2006). According to the CRBV, when firms provide extensive training modules for employees for improving their digital skills and knowledge, their DT implementation is rendered more valuable. Consequently, as an important complementary resource, TP acts as a contingency factor influencing the relationship between DT and ES. We therefore posit that:

H2: TP positively moderates the DT–ES relationship.

3. Methodology

3.1. Sample and data gathering

China's research context holds considerable significance as the world's foremost global manufacturing hub and one of the most energy-intensive nations (Abbasi *et al.*, 2022; Hou and Fang, 2023). Despite this prominence, China faces a critical challenge with continuously rising emissions. Nonetheless, the country has responded with substantial efforts to address ES by establishing ambitious emissions mitigation targets. The Chinese government's commitment to reducing emissions by 60-65% by 2030 demonstrates its dedication to combat climate change and promote ES (Hou and Fang, 2023; Liu *et al.*, 2022). The 14th Five-Year Plan (2021-2025) and the "Made-in-China 2025" initiative outline an ambitious trajectory for China, focusing on digital manufacturing and embracing sustainable green development (Eloot, 2018; Stern and Xie, 2023). These transformative plans aim to shift China from traditional manufacturing practices, characterized by pollution and resource-intensive activities, towards a green and digital economy (Eloot, 2018; Liao *et al.*, 2023; Stern and Xie, 2023). Despite commendable policy efforts, Chinese manufacturers face significant challenges in implementing sustainable digital practices to transition to a low-carbon and net-zero emission economy (Stern and Xie, 2023). These challenges stem from the prevailing deficiency of digital talent with essential proficiencies and expertise (Zhang *et al.*, 2022). The shortage of digital HRM capabilities poses a significant impediment to the progress and potential benefits of DT in the Chinese manufacturing industry (Fan, 2023). Huawei provides a notable example of this challenge and its attempted resolution. In response to the evolving digital landscape, the tech giant has prioritized digital training for its employees, equipping them with a wide range of new digital skills critical for a successful digital transition (Yan, 2020). Achieving digital sustainability transformation requires firms to integrate state-of-the-art digital technologies while providing comprehensive training and development initiatives for their employees. However, it is essential to highlight the scarcity of empirical investigations concerning how DT fosters ES among Chinese manufacturers, particularly considering varying degrees of TP.

Therefore, to empirically test the theoretical model proposed in this study, we gathered survey data from the Chinese manufacturing industry with the help from the Contemporary Service Alliance for Integration of Informatization and Industrialization. We sent the developed questionnaires (described below) to 1500 randomly selected firms and received 307 useable responses (a response rate of 20.47%). A profile of the responding firms is provided in Table 1, which shows that the sampled firms represent a wide variety of characteristics in terms of industry type, number of employees, firm ownership, firm location (i.e., geographical regions within China), and firm age, which instils confidence in the representativeness of the survey data for Chinese industry in general. Most of the respondents held high-level managerial positions, with job tenure of more than six years. Thus, it can be expected that the participants were knowledgeable, and possessed accurate information concerning their firm's DT, ES, and TP.

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3.2. Construct operationalization

Table 2 presents the measurement scales, which were adapted and derived from literature originally published in English. Subsequently, these scales were translated into Chinese, and we employed a back-translation method to ensure conceptual equivalence. Furthermore, we conducted a rigorous comparison between the back-translated English version and the original English version. This process has been substantiated as capable of producing a reliable questionnaire instrument (Yu *et al.,* 2019). Additionally, to improve content validity and reliability of the questionnaire, we conducted a pilot-test with both academics and industry practitioners to obtain their feedback on the measurement items. We developed the measurement scales for DT based on a comprehensive review of prior literature (e.g., Nasiri *et al*., 2020; Nayal *et al*., 2022; Sedera *et al*., 2016) and our observations during the firm visits to several manufacturers in China. DT was measured by seven scale items assessing a firm's ability to transform business processes by developing new digital systems and adopting digital technologies. We developed the measures of TP based on the work of Campion *et al*. (1993) and Huo and Boxall (2018), which included providing employees with adequate technical, team skills, quality, and customer service training, which are important forms of training for DT implementation. These items were measured using a seven-point Likert scale anchored with 1 = strongly disagree and 7 = strongly agree. We adapted the measure of ES from the work of Paulraj (2011) and Yu *et al*. (2020), which included items assessing a firm's environmental performance on air emission, environmental accidents, waste generated, consumption of hazardous materials, and energy savings. We measured the items using a seven-point Likert scale anchored with 1 = much worse than major competitors and 7 = much better than major competitors.

------------------------------ Insert Table 2 ------------------------------

We used firm age (number of years since firm establishment), firm size (number of employees), firm ownership (a form of corporate governance; a dummy variable was used), firm location (geographical regions; a dummy variable was used), and industry type (a dummy variable was used) as control variables in the conceptual model (see Table 1).

3.3. Bias assessment

We carried out a t-test by comparing the early and late respondents on their annual sales and number of employees, and the results show that there is no statistically significant difference between these groups (Hair *et al*., 2010). Thus, non-response bias is unlikely to be an issue in our research.

Survey-based research often grapples with the issue of common method variance (CMV) (Hair *et al.*, 2010). To address this concern, we employed two advanced assessment methods because Harman's single-factor test has faced criticism in previous research (Podsakoff *et al.*, 2012). First, we performed a confirmatory factor analysis (CFA)-based Harman's single-factor test, and the results indicate an unacceptable model fit (χ^2/df = 18.319, CFI = 0.533, IFI = 0.535, TLI = 0.461 and RMSEA = 0.238) (Hair *et al*., 2010). Second, we conducted an additional assessment of CMV using the marker variable technique as described by Lindell and Whitney (2001). We selected job tenure (in years) as the marker variable because it is theoretically unrelated to at least one of the variables in the study, as demonstrated in Table 3. The lowest positive correlation (r = 0.026) between job tenure and the other variables was chosen for the purpose of adjusting the inter-construct correlations and statistical significance. Table 3 illustrates that the significant correlations remained significant even after this adjustment. Based on these results, it is reasonable to conclude that the presence of CMV is unlikely to constitute a significant issue in our research.

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4. Data analyses and results

4.1. Reliability and validity analysis

We conducted exploratory factor analysis (EFA) using a principal component factor analysis with varimax rotation, which generated three factors with eigenvalues greater than 1 that explain 73.982% of the variance (including DT, TP, and ES in Table 2). Table 2 also indicates that the measurement items all have strong loadings on the construct that they were supposed to measure (ranging from 0.675 to 0.911). The results provide support for the unidimensionality of these three theoretical constructs (Hair *et al*., 2010).

To assess construct reliability, we computed Cronbach's alpha coefficient, composite reliability (CR), and corrected item-total correlations (CITC). It can be seen from Table 4 that all Cronbach's alpha values (ranging from 0.911 to 0.932) and CR values (ranging from 0.913 to 0.935) were greater than the commonly acceptance level of 0.70 (Hair *et al*., 2010), and the CITC values (ranging from 0.630 to 0.882) were higher than the minimum acceptable value of 0.30 (Kerlinger, 1986). Thus, the results provide evidence of reliability.

------------------------------ Insert Table 4 ------------------------------

As shown in Table 4, the average variance extracted (AVE) values of three constructs are above the recommended value of 0.50, which suggests that the constructs have convergent validity (Fornell and Larcker, 1981). In addition, Table 3 indicates that the square root of AVE of all three constructs are larger than the inter-construct correlations, which demonstrates evidence for discriminant validity (Fornell and Larcker, 1981).

4.2. Hypothesis testing

We performed regression analysis to test the two hypotheses developed in this study: the effect of DT on ES (H1) and the moderation of TP (H2). The results are presented in Table 5. As indicated in Table 5, variance inflation factor (VIF) values in the three models ranged from 5.730 to 5.838, indicating that multicollinearity is not a problem in this study (Hair *et al*., 2010). Model 3 shows that DT is positively associated with ES ($\beta = 0.231$, $p < 0.001$), which indicates support for H1. The significantly positive coefficient ($\beta = 0.162$, $p < 0.01$) for the interaction term (DT × TP) shown in Model 4 affirms strong support for H2.

------------------------------ Insert Table 5 ------------------------------

To better understand the moderating effect of TP, we plotted the simple slope of the DT–ES relationship at a high and low level of TP (see Figure 2). It is evident from Figure 2 that DT has a significant positive impact on ES, and that this impact is enhanced as the level of TP increases.

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5. Discussion

5.1. Contributions to theory

The theoretical model proposed in our study offers empirically grounded arguments emphasising the importance of DT for gaining an ES advantage. Furthermore, the moderating role of the provision of trainings in strengthening the DT–ES relationship helps to further unravel the performance puzzle of DT. Overall, our findings provide strong support for the proposed theoretical model, i.e., the digitalisation–sustainability convergence is contingent upon the level of TP. Our model extends the RBV and is consistent with the CRBV, providing an additional explanation for the circumstances (i.e., TP) under which DT improves ES. The empirical findings contribute to the sustainability, digitalisation and HRM literature in several important ways.

First, our finding of the significant positive effect of DT on ES provides strong evidence that the adoption of digital technologies enables firms to obtain environmental benefits. This is an important finding, as there has been much debate among academics and managers about the potential benefits and challenges of DT (Block, 2022; Forth *et al*., 2020). One of the most pressing issues from academic researchers, business leaders, and policymakers is whether the implementation of DT can actually deliver expected financial or non-financial benefits. Answering this question, our findings provide compelling evidence that implementing DT can improve environmental performance, significantly contributing to the existing literature on sustainability and digitalisation. As noted above, the prior literature has mostly been conceptual (e.g., Cetindamar *et al.*, 2022; Guandalini, 2022; Koseleva and Ropaite, 2017; Kouhizadeh *et al.*, 2021), case-based (e.g., Demartini *et al.*, 2019), or focused solely on technological issues (e.g., Tang *et al.*, 2022). This result is also found to be consistent with the RBV (Barney, 1991, 2001). As a primary firm resource, updating and improving business processes through the adoption of digital technologies or the development of new digital business models can enable firms to harness environmental benefits (Dubey *et al*., 2019; Nasiri *et al*., 2020).

Second, this study responds to the recent call for further research within the realm of digital sustainability, a new stream of literature (George *et al*., 2021; Guandalini, 2022). Although previous studies, including systematic literature reviews (e.g., Guandalini, 2022; Ranjbari *et al*., 2021), have argued that digitization can be considered a strategic tool to accelerate a sustainability transition, it remains unclear how the implementation of DT can assist ES improvement (George *et al*., 2021; George and Schillebeeckx, 2022). In addition, as one of the key sustainability dimensions, ES has been increasingly acknowledged, which has emphasized the complexity of ES issues for practical actions. For instance, global lockdowns saw economic activities come to a standstill, with massive and immediate macroeconomic benefits (e.g., the reduction of greenhouse gas emissions and air pollution from car transport), but a contemporaneous proliferation of vast volumes of plastic waste due to increased demand for personal protective equipment, consumer face masks, and plastic packaging for food deliveries (Ranjbari *et al*., 2021; Vanapalli *et al*., 2021). To date, there has been little empirical investigation on digital sustainability transformation. To the best of our knowledge, this is the first work demonstrating a significant positive association between DT and ES. Consistent with the RBV, firms that seek to update business processes through implementing digital technologies can improve their ES in terms of pollution prevention (air and water), energy savings, and waste elimination.

Third, another novel finding generated from this study is that we demonstrate the moderating effect of TP on the DT–ES relationship, which can be viewed as a refinement and extension of existing research on training, digitalisation, and sustainability. Both researchers and practitioners have argued that the implementation of DT projects is less about technology and more about people involvement (Frankiewicz and Chamorro-Premuzic, 2020; Philip, 2021), but there remains a lack of empirical evidence to support such claims as work to date has been mostly conceptual (Vial, 2019) and case-based (Dremel *et al*., 2017). The moderation hypothesis proposed in this study, which has not been previously tested empirically, suggests that the degree to which digitalisation improves sustainability depends on complementary firm human resources (i.e., providing training modules for improving employee skills and knowledge). Effective TP is thus a key part of the successful implementation of DT. Consistent with an extended contingency version of the RBV, without TP, DT is more likely to be exploited only in a limited way for sustainability improvement (Marler *et al*., 2006; Philip, 2021); TP is the enhancing factor of DT for sustainable benefits. The extension of the RBV, through the CRBV, is thus strongly supported in suggesting that firms seeking to maximize environmental benefits from the implementation of DT need to invest in providing extensive training and development programmes for employees (i.e., developing complementary resources) (Brandon-Jones *et al*., 2014; Huo and Boxall, 2018; Marler *et al*., 2006). We believe that this study could serve as a basis for a further investigation into the contingency factors (complementary resources) driving the digitalisation–sustainability convergence.

5.2. Contributions to practice

Our research findings offer helpful guidance for managers on how to implement successful DT and promote digitalisation for sustainability improvement. As noted above, several consulting reports have indicated that the success rate of DT is still very low, with the majority (over 70%)

of DT projects failing to deliver expected benefits (Block, 2022). Our study demonstrates that the implementation of DT can deliver real values for ES improvement. Thus, this study suggests that firms that adopt advanced digital technologies (e.g., IoT, and BDA) could be optimistic about their investment returns. Updating business processes and/or developing new digital systems through the adoption of these digital technologies enables firms to improve their ES.

Markman and Krause (2016) observed that firms implementing sustainability practices (i.e., economic, environmental, and social sustainability) must clearly select their strategic priorities, and rank the importance of the environment, society, and economics, with the implication that the environment is the most fundamental sustainability dimension over the long term. The energy crisis caused by the Ukraine war has galvanized the green transition towards the 2050 net zero target. As one of the main sustainability dimensions, ES should be given the highest priority. Our study further suggests that manufacturers, especially from developing countries such as China, should invest in different advanced digital technologies that transform digital into environmental value.

However, this does not mean that managers should expect environmental benefits to inherently arise from the mere implementation of DT; technology and human resources must be calibrated with the organizations' strategic vision and operations, considering multidimensional internal and external stakeholders and activities, in order to realise environmental and other performance outcomes. Many reasons have been identified why DT projects failed, but one of the most prolific is a lack of digital talent with necessary digital skills. Our study suggests that the effect of digitalisation on sustainability improvement depends to some degree upon the provision of employee training programs. Adopting digital technologies for the updating of business processes is a necessary but insufficient resource for enabling ES improvement. Firms need to develop complementary resources, such as providing training programs to enhance employees' digital skills and expertise, which helps strengthen organizational knowledge and capabilities, and thus the effectiveness of digitalisation on sustainability improvement.

6. Conclusions and future research directions

Drawing upon the RBV and the CRBV, this study extends the digitalisation, sustainability, and training literature by demonstrating the moderating effect of TP on the DT–ES relationship. The empirical findings make useful contributions to theory; in particular, this study represents an important advance on the knowledge regarding digital sustainability, a new stream of literature especially in the digital age (George *et al*., 2021; Guandalini, 2022). The empirical findings also offer valuable implications for managers who seek to achieve DT success.

This study has several limitations which also provide directions for future research. First, this study focused on ES, one of the main sustainability dimensions, and previous research has suggested that sustainability is a multidimensional construct consisting of economic, social, and environmental dimensions (Paulraj, 2011; Yu *et al*., 2020). Thus, future research could examine how DT influences all three sustainability dimensions. Second, this study focused on TP, a core complementary firm resource, but previous research has suggested that there are many DT success factors, such as digital transformational leadership, digital culture, and customer needs (Frankiewicz and Chamorro-Premuzic, 2020; Philip, 2021). Thus, future research could explore the moderation and/or mediation effects of such factors on the implementation of DT. Third, we collected survey data from Chinese manufacturing firms in China. To improve the generalisability of the empirical findings obtained from this study, we encourage future research to conduct interview- and/or survey-based study, by collecting data from different regions and industries, in order to verify whether these insights hold true for broader industrial contexts. Fourth, an additional potential limitation of this study pertains to its utilization of a cross-sectional research design. It is noteworthy that the impacts of DT on ES, as investigated in this study, may exhibit temporal fluctuations, particularly within the context of the ever-evolving and uncertain business environment. To provide deeper insights, future research may consider employing a longitudinal study approach to elucidate the dynamic nature of DT's effects on ES. Fifth, in this study, we included a total of five control variables, including firm age, firm size, firm ownership, firm location, and industry type. Future research might also consider additional control variables, such as business network and digital environment (Gong and Ribiere, 2021), to better explore the effect of DT on firm performance.

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Table 1: Sample demographic

	Percent (%)		Percent (%)
Industry type		**Firm location**	
Automobile	35.8	Pearl River Delta	4.6
Chemicals and petrochemicals	5.9	Yangtze River Delta	11.7
Electronics and electrical	10.4	Bohai Sea Economic Area	3.6
Fabricated metal product	17.3	Northeast China	3.3
Food, beverage and alcohol	3.3	Central China	9.4
Rubber and plastics	2.6	Southwest China	65.5
Textiles and apparel	2.0	Northwest China	2.0
Others	22.8		
Number of employees		**Job title**	
1 – 100	6.2	President/CEO	5.9
101 – 200	11.1	Vice President	7.5
201 – 500	17.6	Director	15.0
501 – 1000	10.4	Manager	45.3
1001 – 3000	28.7	Other senior executive	26.4
> 3000	26.1		
Job tenure		**Firm age**	
≤ 5	30.9	≤ 10	16.6
6 – 10	29.0	11 – 20	30.6
> 10	40.1	21 – 30	22.5
Firm ownership		> 30	30.3
State-owned manufacturer	45.9		
Private Chinese manufacturer	31.6		
Wholly foreign-owned manufacturer	6.2		
Joint venture manufacturer	16.3		

Table 2: EFA results: factor loadings

Measurement items	F1	F2	F3
1. Digital transformation			
We develop digital systems for new product development projects	**0.675**	0.149	0.198
We develop digital systems for facilitating market knowledge creation	**0.823**	0.152	0.165
We develop digital systems for external communication (e.g., suppliers, customers, channel members, etc.)	**0.720**	0.207	0.215
Using digital technologies, we address unique business needs swiftly and effectively	**0.763**	0.184	0.228
Using digital technologies, we integrate and build internal and external capabilities in our organization	**0.799**	0.109	0.252
Using digital technologies, we seek out information about new markets, products, and technologies from sources outside the organization	**0.829**	0.103	0.193
Using digital technologies, we manage political and economic risks by promptly responding proactively to them	**0.782**	0.109	0.140
2. Environmental sustainalbity			
Reduction in air emission	0.113	**0.834**	0.222
Reduction in waste (water and/or solid)	0.128	**0.906**	0.177
Decrease in consumption of hazardous/harmful/toxic materials	0.186	**0.868**	0.152
Decrease in frequency for environmental accidents	0.124	**0.911**	0.156
Increase in energy saved due to conservation and efficiency improvements	0.259	**0.767**	0.127
3. Training provision			
We provide our employees with adequate technical training	0.279	0.300	**0.810**
We provide our employees with adequate team skills training (e.g., communication, interpersonal, etc.)	0.271	0.221	**0.837**
We provide our employees with adequate quality training	0.228	0.156	**0.866**
We provide our employees with adequate customer service training	0.308	0.148	**0.809**
Eigenvalues	7.605	2.628	1.605
% of variance	47.531	16.422	10.029
Cumulative explained variance (%)	47.531	63.952	73.982

Table 3: Correlations among constructs

	Mean	S.D.	1	2	3	4	5	6	7	8
1. Firm age	2.664	1.079		0.480**	0.065	0.088	-0.298**	-0.046	0.061	-0.010
2. Firm size	4.225	1.569	0.494**		-0.008	-0.067	-0.116	0.140**	0.152**	0.122*
3. Industry type	3.759	2.737	0.089	0.018		0.084	-0.367**	-0.075	0.025	0.003
4. Firm location	5.055	1.643	0.112	-0.039	0.108		-0.311**	-0.030	-0.006	-0.052
5. Firm ownership	1.928	1.082	-0.264**	-0.087	-0.331**	-0.277**		0.122*	0.072	0.154**
6. Digital transformation	4.773	1.093	-0.019	0.162**	-0.047	-0.003	0.145*	**0.775**	0.378**	0.544**
7. Environmental sustainability	5.494	0.997	0.085	0.174**	0.050	0.020	0.096	0.394**	**0.863**	0.437**
8. Training provision	5.412	1.054	0.016	0.145*	0.029	-0.025	0.176**	0.556**	0.452**	**0.862**
9. Job tenure (marker variable)	2.091	0.839	0.402**	0.260**	-0.026	0.214**	-0.144*	-0.169**	-0.030	-0.109

Note: Unadjusted correlations appear below the diagonal; adjusted correlations for potential common method variance appear above the diagonal; Square root of AVE is represented on the diagonal in bold; ** $p < 0.01$; * $p < 0.05$.

Table 4: Reliability and validity analysis

Constructs	Cronbach's alpha	Composite reliability	AVE	CITC range
Digital transformation	0.911	0.913	0.601	0.630–0.787
Environmental sustainability	0.932	0.935	0.744	0.722–0.882
Training provision	0.920	0.920	0.743	0.787–0.829

Table 5: Results of hypothesis testing

	Model 1	Model 2	Model 3	Model 4
Controls				
Firm age	0.022 (0.318)	0.046 (0.703)	0.034 (0.551)	0.078 (1.243)
Firm size	0.204 (2.929)**	0.087 (1.302)	0.064 (0.998)	0.028 (0.427)
Industry1 (Automobile)	-0.190 (-2.796)**	-0.211 (-3.350)***	-0.158 (-2.571)*	-0.156 (-2.569)*
Industry2 (Fabricated metal product)	-0.095 (-1.488)	-0.052 (-0.875)	0.001 (0.015)	-0.015 (-0.263)
Industry3 (Electronics and electrical)	-0.032 (-0.524)	-0.076 (-1.321)	-0.065 (-1.168)	-0.063 (-1.155)
Location1 (Southwest China)	0.010 (0.118)	-0.051 (-0.668)	-0.077 (-1.061)	-0.066 (-0.912)
Location2 (Yangtze River Delta)	-0.026 (-0.340)	-0.068 (-0.940)	-0.094 (-1.343)	-0.080 (-1.166)
Location3 (Central China)	0.032 (0.446)	-0.043 (-0.638)	-0.077 (-1.192)	-0.072 (-1.136)
Ownership1 (State-owned manufacturer)	-0.242 (-1.810)†	-0.147 (-1.174)	-0.127 (-1.058)	-0.100 (-0.839)
Ownership2 (Private Chinese manufacturer)	-0.108 (-0.893)	-0.120 (-1.065)	-0.128 (-1.182)	-0.115 (-1.081)
Ownership3 (Joint venture manufacturer)	-0.005 (-0.047)	0.022 (0.236)	-0.014 (-0.150)	-0.005 (-0.059)
Independent variables				
Digital transformation (DT)		0.388 (6.931)***	0.231 (3.703)***	0.237 (3.856)***
Training provision (TP)			0.315 (5.028)***	0.315 (5.107)***
Interaction effect				
DT × TP				0.162 (3.160)**
R^2	0.078	0.207	0.270	0.294
Adjust R^2	0.043	0.175	0.238	0.260
F-value	2.254*	6.399***	8.339***	8.694***
Max VIF	5.730	5.800	5.806	5.838

Note: Standardized coefficients (betas) and t-values are reported; dependent variable is environmental sustainability; *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; † $p < 0.10$.

Figure 1: Theoretical model

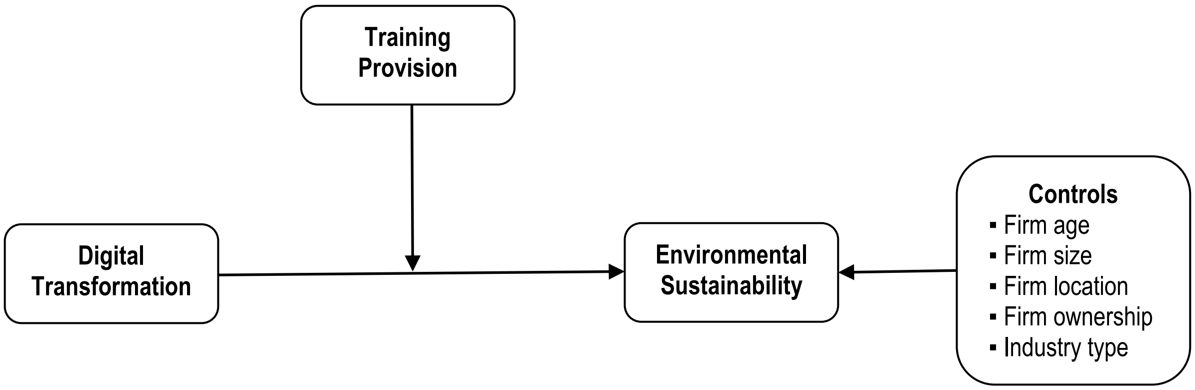

Figure 2: Moderation effect of training provision on the DT–ES relationship