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# Green operational performance in a high-tech industry: Role of green HRM and green knowledge

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ABSTRACT

Prior studies on green HRM often treat it as a stand-alone practice, or a subset of organizational environmental management (EM) system. In this article, consistent with the calls to merge EM systems and TQM, we maintain that green HRM should be operated as a subset of broad TQM system, as a component of TQM-oriented HRM. We identified seven green HRM practices that can be further classified into three sub-systems: competency-enhancing, motivation-enhancing, and opportunity-enhancing. Analyzing data collected from 339 Chinese high-tech companies, we found that the motivation-enhancing and competency-enhancing sub-systems of green HRM affect all four green knowledge-creation and diffusion processes, but the opportunity-enhancing sub-system of green HRM affects only green combination and internalization. We also found that green design is affected by all four knowledge processes, green purchasing is affected by all the green knowledge processes except for green internalization, and green production process is affected only by green externalization and green combination. Our study contributes to business research by taking a first step toward integrating green HRM into the broader TQM framework and investigating its performance implication from a TQM perspective.

## 1. Introduction

In recent years, as sustainability and environmental protection become important global concerns, companies are increasingly paying attention to their green performance (Achi et al., 2022; Anwar et al., 2023; Rahman, 2023). Business research has since identified various factors that may influence green performance, including for instance corporate economic conditions (Campbell, 2007; Sureeyatanapas et al., 2018), company size (Darnall et al., 2009; Sureeyatanapas et al., 2018), company ownership (Wu and Ma, 2016), and employees' in-role and extra-role green behaviors (Dumont et al., 2017; Harvey et al., 2013; Paillé et al., 2014). In this direction, the HRM aspect of green management, termed green HRM (Dumont et al., 2017; Obeidat et al., 2020), becomes increasingly recognized as it is the human resources that "stimulate the success of [the organization's] integration with the environmental management" (Saeed et al., 2019, p. 425).

Research on green HRM facilitates knowledge about the processes and activities enacted in various areas of business and management from a micro-foundation perspective (Minbaeva, 2013). So far most of the prior studies treat green HRM as a standalone management practice or a subset of organizational environmental management (EM) system (e.g., Dumont et al., 2017; Harvey et al., 2013; Obeidat et al., 2020). However, as companies increasingly emphasize on implementation of one broad, organization-wide management system, such as total quality management (TQM), ISO 9000, etc., in the past several decades, one question begs answer: could green HRM be integrated into a broad management system and operate as a component of the system? According to our best knowledge, little attention has been paid to this perspective by prior studies.

The challenge of positioning green HRM in the broader management process is the under-specification of how it might influence organizations' desired outcomes such as green operational performance. Prior business research has suggested that an organization's HRM system may not directly affect work outcomes, but rather influences outcomes through social and psychological processes (Dumont et al., 2017; Jiang et al., 2012). To date, most studies have focused only on the of green

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HRM on individual employees and regarded employees' in-role and extra-role green behaviors as the key mechanism linking green HRM to environmental performance (e.g., Dumont et al., 2017; Kim et al., 2019; Pham et al., 2019; Saeed et al., 2019; Shen et al., 2018; Singh et al., 2019; Singh et al., 2020). These risks producing an incomplete picture because as a key management function, HRM practices impact affect efficiency and effectiveness of broader business processes and activities at team and organizational level, not just individual behaviors. Therefore, business research is ye to provide a complete picture of how green HRM affects organizational outcomes through various intra-organizational business processes.

In this study, we intend to fill these research limitations by examining the relationships between green HRM and green operational performance from the perspective of TQM. Specifically, consistent with the calls to merge EM systems and TQM (e.g., Molina-Azorín et al., 2009; Yang and Kang, 2020; Zeng et al., 2005), we maintain that green HRM processes and activities should be operated as a subset of broad TQM system, as a component of TQM-oriented HRM. We particularly focus on one critical mechanism linking green HRM and organizational outcomes, namely, green knowledge creation and diffusion, which is a mediator related to organizational level business processes. As researchers are increasingly emphasizing the importance of involving ecological and social responsibilities into their knowledge development and management (Bouncken et al., 2023; Chin et al., 2022; Khan et al., 2021), we believe that green knowledge creation and diffusion are essential to firms' green performance. Accordingly, we develop an integrated model depicting the relationships among green HRM activities and processes, green knowledge processes, and green operations outcomes. The TQM literature has suggested that a key mechanism through which TQM practices affect organizational outcomes is by promoting knowledge creation and utilization (Hendricks & Singhal, 1997; Ong and Tan, 2018; Wruck & Jensen, 1994). The EM literature also suggests that most environmental projects must combine various knowledge and/or develop new knowledge (Albort-Morant et al., 2018; Fryxell & Lo, 2003; Renwick et al., 2013; Shahzad et al., 2020). Additionally, the HRM literature maintains that one of the key roles of HRM is to facilitate knowledge creation in an organization, which subsequently affects organizational outcomes (Edvardsson, 2008; Giudice et al., 2021a, 2021b; Lopez-Cabrales et al., 2009; Minbaeva et al., 2009). Accordingly, we argue that green HRM could enhance green operations by facilitating green knowledge-creation and diffusion processes. We specifically focus on the four knowledge-creation and diffusion processes identified by Nonaka and Takeuchi (1995), namely, socialization, externalization, combination, and internalization. We maintain that these four processes mediate the relationship between green HRM and green operational performance.

We empirically test our research model in the context of 339 high-tech companies located in four provinces in China. The remainder of

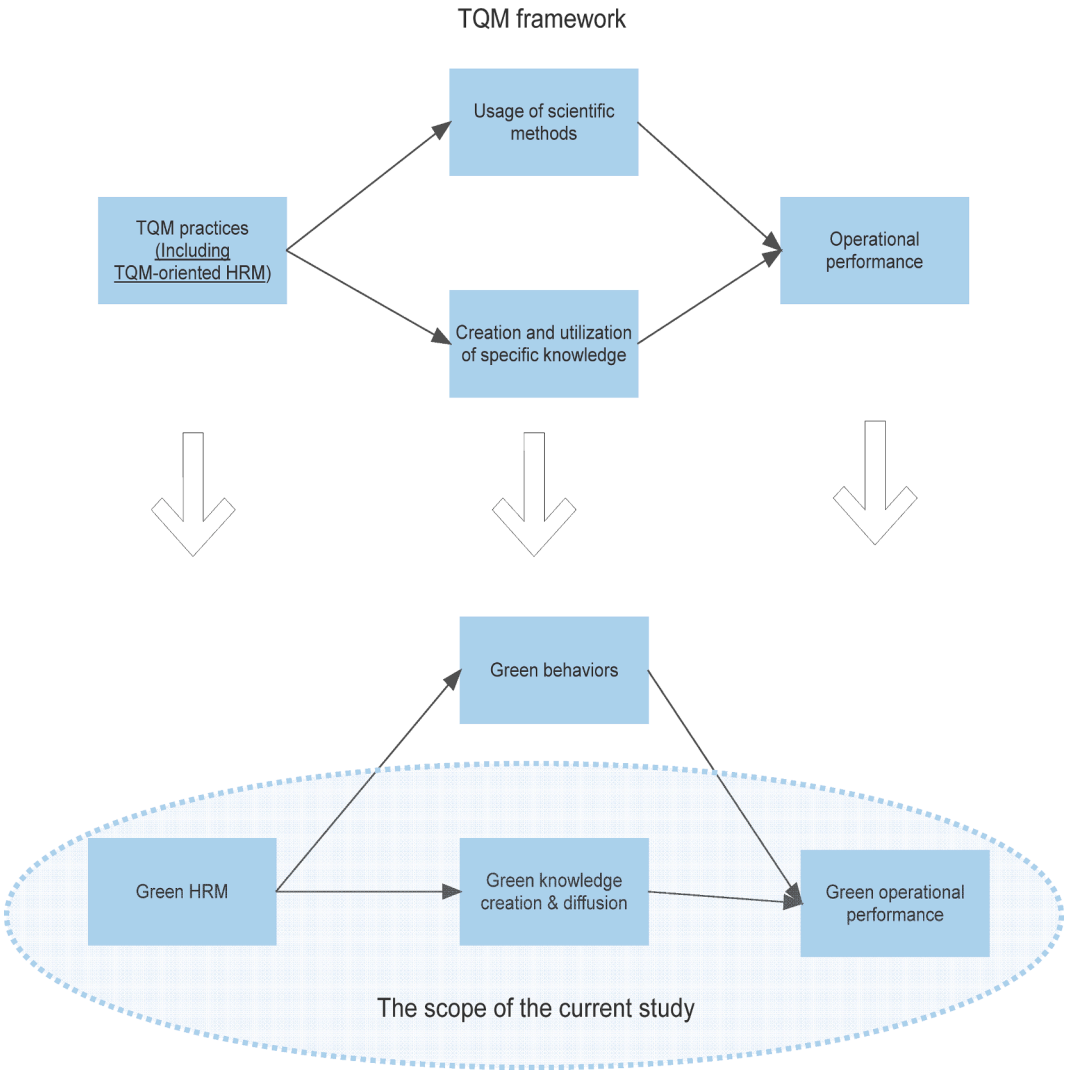


**Fig. 1.** The corresponding relationship between TQM and green HRM frameworks. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the article is organized as follows. The theoretical foundation section provides an overview of the relationship between TQM and HRM, the relationship between TQM and EM, the key dimensions of green HRM, and the relationship between green HRM and green knowledge. We then develop our research hypotheses and present the research methodology and results of the analysis. Next, we discuss our findings, theoretical contributions, and the implications for practitioners. Finally, we address the study limitations and offer directions for future research.

## 2. Theoretical foundation

The current study maintains that green HRM processes and activities can be considered a sub-system of TQM-oriented HRM. Therefore, from the TQM perspective, green HRM should facilitate green behaviors and green knowledge creation and diffusion. These two factors then affect green operational performance, a key TQM performance indicator. The relationships between TQM and green HRM frameworks are presented in Fig. 1. For the current study, we focus on the linkage of green HRM -> green knowledge creation and diffusion -> green operational performance. We discuss the theoretical foundations of the study in the following sections.

### 2.1. TQM and HRM

TQM is defined as a holistic management system philosophy and set of practices that aim to continuously improve and sustain products and services, reduce costs, satisfy customers and employees, and improve financial performance by capitalizing on the involvement of management, workforce, suppliers, and customers (Cua et al., 2001; Powell, 1995). The TQM movement has dramatically influenced HRM in the past several decades. For example, TQM's emphasis on activities such as employee empowerment, employee involvement, and teamwork has made these practices prominent elements of modern HRM (Amsden et al., 1996; Korukonda & Watson, 1999; Verma et al., 2022). Waldman (1994) maintains that TQM provides a system-oriented perspective to HRM, which traditionally focuses on assessing individual difference leading to variation in work performance.

It is argued that all the content areas of TQM contain human resource (HR) implications (Dean & Bowen, 1994). Specifically, the principles of TQM are generally relevant to HRM. According to Sitkin et al. (1994), TQM emphasizes three significant principles. First, TQM focuses on customer satisfaction by developing an incentive system that considers that all members of an organization are accountable to either internal or external stakeholders, for example, consumers, stockholders, and employees. HRM system should facilitate organization-wide efforts to satisfy the demands of these stakeholders. Second, TQM stresses continuous improvement by holding that organizations must continuously enhance the reliability and control of performance (Ershadi et al., 2019; Sitkin et al., 1994). To do so, organizations must continuously develop new skills and capabilities. HR should make efforts to facilitate this process, given that HR plays a critical role in creating and spreading new knowledge in an organization (Chuang et al., 2016). Third, TQM treats the organization as a total system by suggesting that simple, patchwork solutions cannot resolve complex production and service problems. TQM maintains that such problems require an assessment of the entire production chain to identify the root causes of the problems and find solutions. This principle implies that organizations must involve individual employees as a critical part of the problem-solving mechanism (Bowen & Lawler, 1992; Cavallone and Palumbo, 2021). This requires HR to encourage employees to participate in solving problems (Jun et al., 2006). In summary, HR plays a critical role in implementing TQM. Organizations must develop HRM systems that are aligned with their TQM strategies (Dean & Bowen, 1994).

### 2.2. TQM and EM

A principal goal of TQM is to achieve excellent operational performance and thereby ensure customer satisfaction (Hendricks & Singhal, 1997; Samson & Terziovski, 1999; Sousa & Voss, 2002). Traditionally, the TQM literature has emphasized operational outcomes such as quality, costs, and inventory performance (e.g., Kaynak, 2003; Kebede Adem and Virdi, 2021; Reed et al., 1996; Samson & Terziovski, 1999; Westphal et al., 1997). As environmental sustainability has become one of humanity's most critical challenges, TQM researchers have begun to pay attention to environmental performance outcomes. It is argued that TQM practices, focusing on improving the efficiency of organizational processes, could also facilitate green operations (Abbas, 2019; Moraes et al., 2019; Molina-Azorín et al., 2009; Pereira-Moliner et al., 2012). Green operations refer to the efforts made by organizations to integrate environmental considerations in their operations management, which involves the set of skills and concepts that allow organizations to structure and manage their business processes, thereby ensuring they consider the effect of their operations on people and the environment (Kleindorfer et al., 2005; Liu et al., 2017). Following Liu et al. (2017), we examine the performance of three aspects of green operations in this study. The first is green design, which refers to the systematic consideration of design performance concerning the environment, health, and safety, as well as to the sustainability of objectives over the entire product and process life cycle (Handfield et al., 2001; Liu et al., 2017). The second is green purchasing, which refers to selecting suppliers that deliver green products greenly and collaborating with suppliers to improve green performance (Blome et al., 2014; Liu et al., 2017). The third is the green production process, which focuses on reducing the harmful environmental effects of production (Liu et al., 2017; Orlando et al., 2022). As a component of overall operational performance, it is argued that green operational performance is another critical goal of TQM (Chen & Wu, 2015; Hanna & Rocky Newman, 1995).

Further, there are calls in the literature to integrate TQM and EM, such that one single system could be implemented by organizations to achieve performance excellency (Karapetrovic & Willborn, 1998; Molina-Azorín et al., 2009; Wilkinson & Dale, 1999; Zeng et al., 2005). TQM and EM programs require implementation factors such as leadership, people management, training, stakeholder focus, etc. (Molina-Azorín et al., 2009; Pereira-Moliner et al., 2012). Indeed, the International Organization for Standardization (ISO) has made efforts to make their quality management standard (ISO 9001), which reflects the principles of TQM, and their EM standard (ISO 14001) more compatible with each other, such that "common elements of the standards can be implemented in a shared manner, in whole or in part, by organizations without unnecessary duplication or the imposition of conflicting requirements" (ISO, 1998). Such common elements could lead to process improvement, including environmental outcomes such as improving friendliness to the environment and reducing waste (Molina-Azorín et al., 2009). In the same vein, this study argues that green HRM is one of the common elements of TQM and EM.

### 2.3. Key dimensions of green HRM from the TQM perspective

As discussed, TQM practices can significantly affect green operational performance. This study maintains that green HRM is one of the TQM practices to facilitate such performance. A great deal of early research on TQM does not explicitly identify HRM as a critical dimension of TQM (e.g., Ahire et al., 1996; Black & Porter, 1996; Flynn et al., 1994), but all of these studies include some HRM elements, for example, training. Later, several studies began to emphasize that HRM constitutes a critical component of TQM (e.g., Dubey & Gunasekaran, 2015; García-Alcaraz et al., 2019; Jun et al., 2006; Ooi, 2014; Wolor et al., 2022). The critical components of TQM-oriented HRM include activities and processes such as worker selection, employee empowerment/involvement, training, teamwork, appraisal, and reward systems (Flynn et al., 1994;

García-Alcaraz et al., 2019; Jun et al., 2006; Ooi, 2014; Wolor et al., 2022).

Given that green operational performance has become an essential goal of TQM, we maintain that TQM-oriented HRM must include elements that facilitate green operations and overall green performance (i.e., green HRM practices). Prior studies have identified several key green HRM processes and activities, including performance management and appraisal, pay and reward systems, recruitment and selection, training, teamwork, employee involvement, and employee empowerment (Moraes et al., 2019; e.g., Renwick et al., 2013; Shah, 2019). It is important to note that these HRM practices are generally consistent with the TQM-oriented HRM practices mentioned above. Therefore, green HRM could be operated as a sub-system of TQM-oriented HRM. For example, in a TQM-oriented HRM system, performance appraisal may include criteria related to green performance. The corresponding relationships between TQM-oriented HRM and green HRM practices are presented in Table 1.

Following Chuang et al. (2016), we further classify TQM-oriented HRM and green HRM practices by adopting the widely used ability–motivation–opportunity framework. This framework suggests that all employee performances are functions of their ability, motivation, and opportunity to perform (Sterling & Boxall, 2013). Accordingly, we classify green HRM practices into the following three sub-systems: competency-enhancing, motivation-enhancing, and opportunity-enhancing (see Table 1). First, the competency-enhancing sub-system includes HR practices related to employee recruitment, selection, and training. This sub-system aims to staff the organization with employees that have and will continuously improve the knowledge, skill, and ability needed for TQM/EM programs (Chuang et al., 2016). Second, the motivation-enhancing sub-system includes performance appraisal and reward practices. This sub-system aims to drive employees' attention to TQM/EM programs and then induce and enhance their discretionary efforts (Chuang et al., 2016). Third, the opportunity-enhancing sub-system includes employee empowerment, involvement, and teamwork. This sub-system aims to create appropriate work conditions for employees who have the required competencies and adequate motivation to engage in TQM/EM programs (Chuang et al., 2016).

### 2.4. Green HRM and green knowledge

The preceding discussion suggests that green HRM affects green operational performance under the framework of TQM. One remaining question is *how* green HRM affects green operational performance. Prior studies have established that green HRM could affect employees' in-role and extra-role behaviors (e.g., Dumont et al., 2017; Kim et al., 2019; Pham et al., 2019; Saeed et al., 2019; Shen et al., 2018), which arguably could facilitate green operations. However, HRM could influence organizational outcomes through various social and psychological processes (Dumont et al., 2017; Jiang et al., 2012). Employee behaviors are not the only mechanism linking green HRM and operations. The current study explores the mechanism between the two constructs from the TQM perspective. TQM practices facilitate performance by enabling organizations to effectively utilize their human and physical assets to achieve two goals: (1) encourage the creation and utilization of specific knowledge; (2) encourage the use of scientific methods in everyday decision making throughout the organization (Hendricks & Singhal, 1997; Ong and Tan, 2018; Sitkin et al., 1994; Wruck & Jensen, 1994) (see Fig. 1). In consideration of this perspective, employees' in-role and extra-role green behaviors could be considered "behaviors of using scientific methods related to environmental protection". The linkage between green HRM and such behaviors could be considered to represent "organizations effectively using human resources to encourage the use of scientific methods".

However, the TQM performance mechanisms mentioned above suggest another key organizational process between green HRM and operational performance: knowledge creation and diffusion. Arguably, for green operation, "encourage the creation of specific knowledge" requires green HRM to facilitate the creation of knowledge related to environmental protection and green operations (hereafter, green knowledge) in the organization; whereas "encourage usage of scientific methods" requires green HRM to facilitate diffusion of green knowledge. Therefore, we maintain that green knowledge-creation and diffusion processes constitute a key organizational process linking green HRM to green operational performance.

To identify this mechanism, we draw on Nonaka's theory of organizational knowledge creation and diffusion (Nonaka, 1994; Nonaka & Konno, 1998; Nonaka & Takeuchi, 1995). This theory focuses on the conversion processes between tacit and explicit knowledge, which

**Table 1**
TQM oriented HRM vs green HRM.

| HR sub-system | Components of TQM-oriented HRM | Components of green HRM |
|---|---|---|
| Competency-enhancing: the purpose of the system is to staff the organization with employees that have and will continuously improve the knowledge, skill, and ability needed for TQM/EM programs (Chuang et al., 2016) | *Worker selection:* recruitment and selection of workers to develop a reliable and committed workforce loyal to the organization's goals, including quality performance (Flynn et al., 1994). | *Green recruitment and selection:* using green criteria to hire applicants with green awareness, knowledge, and skills (Shah, 2019). |
| | *Training:* trainings that provide opportunities in which employees can broaden their knowledge and skills related to TQM (Jun et al., 2006) | *Green training*: a system of activities motivating employees to learn environmental protection skills and pay attention to environmental issues (Tang et al., 2018) |
| Motivation-enhancing: the purpose of the system is to drive employees' attention to TQM/EM programs and then to induce and enhance their discretionary effort (Chuang et al., 2016) | *Appraisal system:* a system evaluating the quality of employees' work and their performance and providing feedback to satisfy their development needs (Jun et al., 2006). | *Green performance appraisal system:* a system of evaluating employees' green performance in the process of environmental management (Tang et al., 2018). |
| | *Reward system:* a system providing financial and non-financial rewards for individuals and teams who contribute to TQM efforts (Jun et al., 2006) | *Green performance reward system:* a system offering employees financial and non-financial rewards on their green performance (Tang et al., 2018). |
| Opportunity-enhancing: the purpose of the system is to create appropriate conditions for employees who have the needed competencies and adequate motivation to engage in TQM/EM programs (Chuang et al., 2016) | *Employee empowerment:* authorizing employees to participate in the decision-making process, inspect for their jobs, and find and fix problems (Jun et al., 2006). | *Green employee empowerment:* encouraging and empowering employees to take actions that they think would improve the environmental performance of the company (Renwick et al., 2013) |
| | *Employee involvement*: a formal system to encourage and track employees for their participation in TQM programs (Ahire et al., 1996) | *Green employee involvement:* a system providing employees with opportunities to engage in quality improvement and problem-solving on environmental issues in the production process (Tang et al., 2018) |
| | *Teamwork:* quality circles, quality improvement teams, and cross-functional teams that allow decentralized decision-making by the teams (Flynn et al., 1994; Jun et al., 2006) | *Green teamwork*: Teams and teamwork designed to solve environmental problems (Moraes et al., 2019) |

create and disseminate knowledge in an organization to establish an organizational knowledge base. Specifically, explicit knowledge is transmittable in informal, systematic language, while tacit knowledge involves cognitive and technical elements, which are difficult to formalize and communicate (Nonaka, 1994) and involves four knowledge conversion processes (see Fig. 2) as, *socialization* (tacit to tacit): *externalization* (tacit to explicit), *combination* (explicit to explicit), and *internalization* (explicit to tacit).

In this study, we maintain that green HRM practices, as a subset of TQM-oriented HRM practices, facilitate the four processes related to green knowledge creation and diffusion in organizations. The processes subsequently affect green operational performance (see Fig. 2). From the perspective of knowledge management, green HRM practices, along with the green knowledge creation and diffusion processes, are critical to green knowledge management system. It is argued that organizations need to design knowledge management processes and systems to leverage the expertise of the workforce and to add new value by enabling employees to collaborate on knowledge development and diffusion to meet organizational needs (Nowacki and Bachnik, 2016). Particularly, organizational knowledge management system needs to promote collaborative knowledge development and diffusion within an organization, and encourages and involves employees to explore and

## Figure 2. Research model

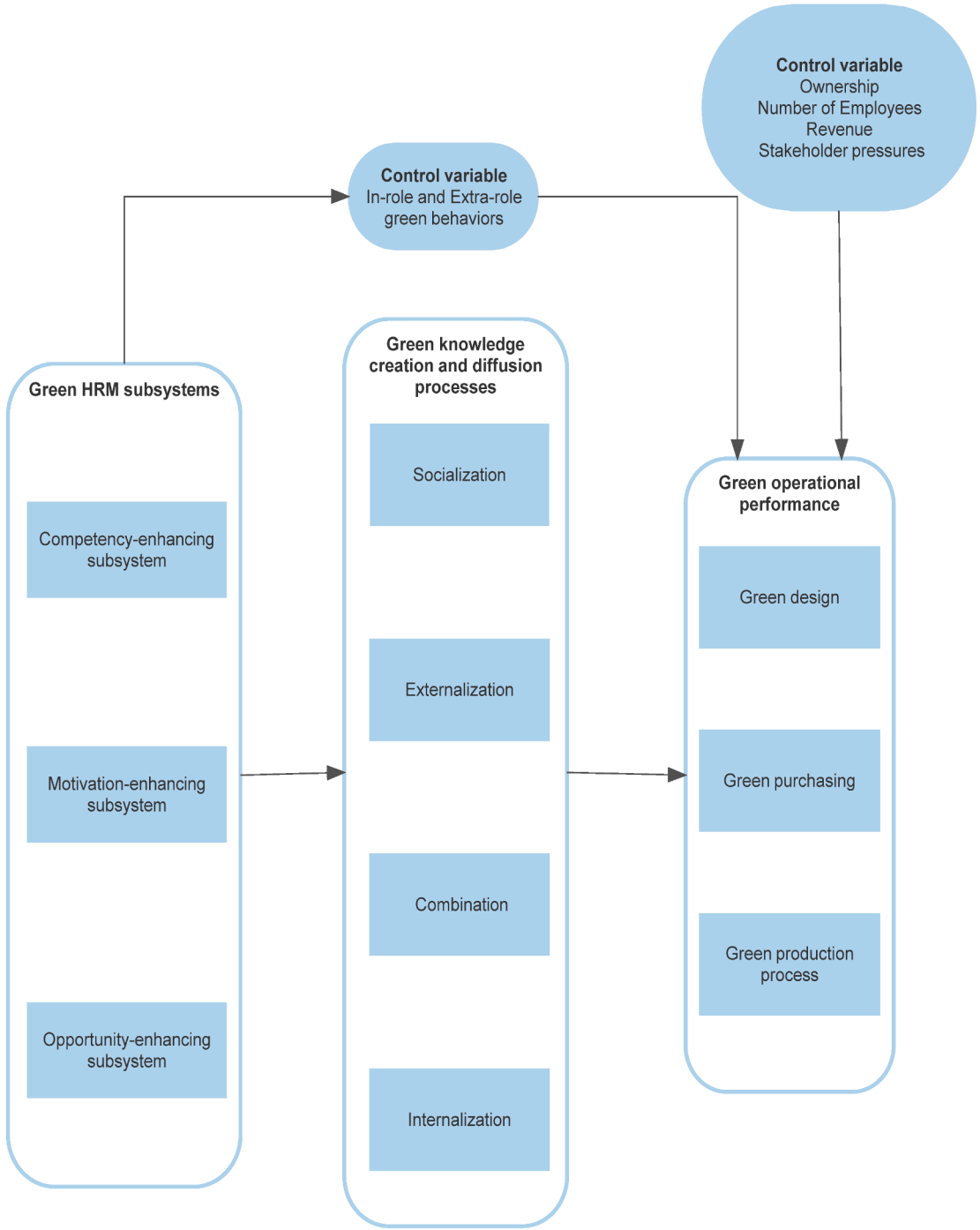


**Fig. 2.** Research model.

integrate internal and external knowledge (Chaurasia et al., 2020; Papa et al., 2021). This is especially important for knowledge creation and diffusion related to environmental protection and sustainability (Chaurasia et al., 2020). In this sense, green HRM practices and the four knowledge creation and diffusion processes together enable firms to effectively develop and manage their green knowledge.

## 3. Research hypotheses

This study considers green HRM a subset of TQM-oriented HRM. One key mechanism through which TQM practices affect organizational outcomes is by encouraging the creation and utilization of specific Knowledge (Hendricks & Singhal, 1997; Ong and Tan, 2018; Wruck & Jensen, 1994). Accordingly, we maintain that from the TQM perspective, the three green HRM sub-systems could affect the four green knowledge-creation and diffusion processes, which subsequently affect green operational performance. Our research model is presented in Fig. 2.

First, the green competency-enhancing sub-system, which consists of green recruitment/selection and green training, enables firms to identify and prepare qualified employees for EM practices. The TQM literature suggests that an appropriate recruitment and selection system enables companies to develop a reliable and committed workforce loyal to the organization's goals, including quality management (Flynn et al., 1994; Khan et al., 2020). In addition, successful training and development programs can create favorable employee attitudes and provide employees with the knowledge and skills to better perform their jobs (Boon et al., 2007; Flynn et al., 1994; Khan et al., 2020; Jun et al., 2006). Similarly, the green HRM literature maintains that green recruitment and selection enable firms to identify individuals committed to environmental issues and are valuable to the organization concerning EM (Dumont et al., 2017; Shah, 2019; Tang et al., 2018). Further, green training enables employees to increase their environmental protection awareness, knowledge, and skills (Cherian & Jacob, 2012; Dumont et al., 2017; Tang et al., 2018). Finally, knowledge management literature also suggests that managers must customize traditional HRM practices such as recruitment and training. Specifically, they need to select talented people that could contribute to their organizations' knowledge base, as well as those who are capable of learning necessary knowledge; they also need to design and implement training and development activities to authorize the fit between employees' present and requisite knowledge and skills (Chaudhuri et al., 2021; Castellani et al., 2021; Kianto et al., 2017; Michaelis et al., 2021).

Accordingly, we maintain that the green competency-enhancing subsystem facilitates green knowledge creation and diffusion in organizations. Nonaka (1994) maintains that commitment is one of the most critical components for promoting the formation of new knowledge within an organization. Between the two green competency-enhancing practices, green recruitment and selection can help ensure that individual employees have necessary green awareness and are willing to commit to environmental protection (Shah, 2019; Tang et al., 2018), while green training can enhance the green awareness of employees (Dumont et al., 2017; Shah, 2019; Tang et al., 2018). Thus, the green competency-enhancing sub-system helps to facilitate employee commitment to environmental protection, which subsequently leads to green knowledge creation and diffusion.

Moreover, the four knowledge-creation and diffusion processes identified by Nonaka (1994) require employees to possess various skills and knowledge ad hoc. First, socialization involves sharing tacit knowledge between individuals, which often occurs through physical proximity (Nonaka, 1994; Nonaka & Konno, 1998). This requires employee awareness of group development processes and team behaviors that facilitate communication and understanding between members (Linderman et al., 2004). Such awareness could be developed through practical green training. Organizations may also recruit employees familiar with green teamwork for such socialization processes (green selection). Second, externalization requires the expression of tacit knowledge and its translation to comprehensible forms that can be understood by others (Nonaka, 1994; Nonaka & Konno, 1998). This requires using various tools (e.g., brainstorming) to capture the tacit knowledge of individuals and externalize this knowledge in the form of an idea or concept that can be understood by others (Linderman et al., 2004). Green recruitment and selection can help organizations identify employees with such skills, and practical green training can teach employees these tools to facilitate externalization. Third, combination involves converting explicit knowledge into a more complex set of explicit Knowledge (Nonaka, 1994; Nonaka & Konno, 1998). This process requires employees to collect external knowledge from inside and outside the organization, combine the knowledge, and transfer the knowledge by using presentations or meetings (Nonaka & Konno, 1998). The competency-enhancing system can facilitate this process by identifying employees with relevant skills such as green knowledge collection, organization, and presentation (green recruitment and selection) or teaching employees such skills (green training). Fourth, internalization refers to converting explicit knowledge into an organization's tacit knowledge, which requires individuals to identify the knowledge relevant to themselves within the organizational Knowledge (Nonaka, 1994; Nonaka & Konno, 1998). Green recruitment and selection can help organizations find employees who could identify this relevant knowledge. Effective green training can allow individual employees to assess the knowledge realm of their group and the entire organization, thereby facilitating internalization (Nonaka & Konno, 1998).

In summary, the green competency-enhancing sub-system enhances employee environmental protection awareness and helps organizations to identify and/or develop employees with the skills and knowledge necessary for organizational green knowledge creation and diffusion. Thus, we present the following hypotheses:

> ***H1:*** *The green competency-enhancing sub-system is positively related to (a). green knowledge socialization, (b). green knowledge externalization, (c), green knowledge combination, and (d). green knowledge internalization.*

Second, the green motivation-enhancing sub-system, which involves green performance appraisal and reward practices, drives employees' attention to environmental protection and motivates them to engage in specific EM programs (Chuang et al., 2016). The TQM literature emphasizes that performance appraisal and reward systems must be brought in line with TQM principles (Cardy & Dobbins, 1996; Khan et al., 2020; Lai et al., 2006). Such systems need to encourage the development of knowledge or skills and offer personal recognition for quality improvement efforts (Jun et al., 2006; Palanichamy & Arunachalam, 2017). Similarly, the green HRM literature emphasizes that a performance appraisal system should include green performance indicators, including indicators related to green knowledge creation and diffusion; whereas a green reward system must recognize and compensate employees' green efforts (Dumont et al., 2017; Shah, 2019; Tang et al., 2018). Finally, knowledge management literature suggests that firms need to develop knowledge-based performance assessment and compensation, such that they can assess employees according to their contributions to organizations knowledge processes and motivate employees to make efforts to share knowledge and generate new ideas (Kianto et al., 2017). Thus, green performance appraisal and reward practices are consistent with the spirit of TQM and knowledge management and are thus able to encourage employees to engage in quality improvement initiatives related to environmental protection, including green knowledge creation and diffusion.

Precisely, green performance appraisal and reward practices align the interests of individuals with organizational green goals (Shah, 2019; Tang et al., 2018), which facilitates employees' extrinsic motivation (i.e., the motivation driven by the goal of obtaining extrinsic work rewards or outcomes) (Gottschalg & Zollo, 2007). Therefore, employees become

more responsive and concerned with EM performance (Tang et al., 2018). They are more likely to engage in green practices such as green knowledge creation and diffusion, which could help them achieve better green performance as demanded by the organizational performance appraisal and reward system. Additionally, offering rewards for the best green ideas could encourage employees to seek new green knowledge and share the knowledge with others to generate creative insight (Chuang et al., 2016; Lopez-Cabrales et al., 2009). Empirically, Chuang et al. (2016) demonstrate that motivation-enhancing HRM practices constitute an essential component of HRM systems that promote knowledge acquisition and sharing. Similarly, we propose that the green motivation-enhancing sub-system facilitates the four green knowledge-creation and diffusion processes. Therefore, we propose the following hypotheses:

***H2:*** *The green motivation-enhancing sub-system is positively related to (a). green knowledge Socialization, (b). green knowledge externalization, (c). green knowledge Combination, and (d). green knowledge internalization.*

Third, the opportunity-enhancing sub-system provides opportunities for individual employees to engage in EM programs. This sub-system includes employee empowerment, employee involvement, and teamwork, which have long been emphasized in the TQM literature. The knowledge management literature also suggests that employees will consider the opportunity to contribute to the formation of their organizations' knowledge and intellectual capitals as enjoyable and personally meaningful activity (Fait et al., 2021). Therefore, when the sub-system offered employees opportunities, employees could be motivated to contribute to green knowledge development and diffusion.

Expressly, employee empowerment authorizes employees to participate in decision-making processes, inspect their jobs, and find and fix problems (Gözükara et al.,2019; Jun et al., 2006; Ong and Tan, 2018). On the other hand, employee involvement allows the subordinate to gain greater control and freedom of choice concerning bridging the communication gap between management and workers (Bakotić & Rogošić, 2017; Noah, 2008). Teamwork often takes the form of quality circles, quality improvement teams, and cross-functional teams, which enable employees to work together to improve their performance and self-efficacy (Jun et al., 2006; Verma et al., 2022). These practices are also emphasized in the green HRM literature: green empowerment encourages employees to take action to improve EM (Renwick et al., 2013); green involvement provides employees with opportunities to participate in EM (Tang et al., 2018); green teamwork allows employees to work together to solve environmental problems (Moraes et al., 2019).

Accordingly, we maintain that the green opportunity-enhancing sub-system enhances the four green knowledge-creation and diffusion processes. Nonaka and Konno (1998) emphasize that the four processes must occur in *Ba*, shared physical, virtual, and/or mental spaces that serve as a foundation for knowledge creation. Knowledge is embedded in shared spaces should be acquired by employees through their own experience or reflection on the experience of others. The current study maintains that the opportunity-enhancing sub-system creates *Ba* to enable knowledge creation and diffusion in organizations. Specifically, green employee empowerment enables employees to take actions related to EM. Employees must interact with others, including peers and supervisors, and receive feedback on their actions during the process. This creates a shared space for knowledge to be created, organized and disseminated. Employee involvement allows employees to become involved and transcend their limited perspectives or boundaries and enter a broader organizational space that facilitates knowledge creation and dissemination (Nonaka & Konno, 1998). Teamwork creates a space where individuals can interact and participate in the knowledge creation and exchange process (Chuang et al., 2016; Nonaka & Konno, 1998). Thus, the green opportunity-enhancing sub-system can create shared knowledge space in organizations, or *Ba*, the fundamental condition for green knowledge creation and diffusion. Thus, we present the following hypotheses:

***H3:*** *The green opportunity-enhancing sub-system is positively related to green knowledge Socialization, (b). green knowledge externalization, (c). green knowledge Combination, and (d). green knowledge internalization.*

Finally, we maintain that the four knowledge creation processes enhance green operations. The TQM literature has long emphasized the importance of explicit knowledge such as TQM principals, practices, and statistical tools (Abtew et al., 2018; e.g., Park et al., 2001; Sitkin et al., 1994; Wruck & Jensen, 1994) and tacit knowledge such as problem-solving skills and know-how (e.g., Lapré et al., 2000; Mukherjee et al., 1998; Sideras, 2022; Wruck & Jensen, 1994). We argue that knowledge creation and diffusion is the main mechanism through which TQM facilitates organizational outcomes (Hendricks & Singhal, 1997; Ong and Tan, 2018; Wruck & Jensen, 1994). Accordingly, Linderman et al. (2004) maintain that the four knowledge-creation and diffusion processes in organizations enhance organizational knowledge base and performance.

Similarly, we maintain that green knowledge also involves explicit knowledge (e.g., environmental regulations, green operational procedures, and techniques) and tacit knowledge (e.g., green problem-solving skills, know-how). Therefore, from the TQM perspective, it is vital for organizations to engage in green knowledge creation and diffusion, thereby facilitating green operational performance. First, *socialization* allows individuals to interact with others inside and outside their organizations, and develop and learn tactic knowledge by observation, imitation, and practices (Leal-Millán et al., 2016; Nonaka, 1994; Scuotto et al., 2022). As such, green knowledge socialization enables creation and diffusion of green tactic knowledges in organizations, thereby facilitating green performance. For example, Triana and Ortolano (2005) report that in Colombia's Cauca Valley Corporation, *socialization* processes such as extensive internal meetings and discussions enhance the organization's green performance. Albort-Morant et al. (2018) also shows that the ability of a firm's employees to share information with supply chain partners, through means such as meeting and joint teams, greatly affect green innovation. Therefore,

***H4:*** *Green knowledge socialization is positively related to (a) green design, (b) green purchasing, and (c) green production process.*

Second, *externalization* convert tactic knowledge into explicit knowledge (Nonaka, 1994). It is a process of concept creation and is often triggered by dialogue and collective reflection (Linderman et al., 2004). During the green externalization process, individuals could use metaphors, analogies, and models to establish design concepts and prototypes that could facilitate firms' green performance (Linderman et al., 2004; Nonaka and Takeuchi, 1995). For example, Denton (1999) reports that in Dow Chemical, *externalization* process that employees articulating their tacit knowledge into explicit concepts play a critical role in developing a Waste Elimination Idea Book annually within its organization. The Idea Book significantly contribute to the company's efforts to reduce pollution. Therefore,

***H5:*** *Green knowledge externalization is positively related to (a) green design, (b) green purchasing, and (c) green production process.*

Third, *combination* is a social process that combine different bodies of explicit knowledge held by individuals (Nonaka, 1994). It involves reconfiguration of existing information through sorting, adding, combining, categorizing, and recontextualizing of explicit knowledge, which may lead to creation of new knowledge (Ciampi et al., 2020; Linderman et al., 2004). Therefore, green knowledge combination allows a firm to collect green experience and successful green techniques inside and outside the organization and implement them organization-

wide. By doing so, the firm can facilitate its green performance. In the example of Dow Chemical, development of Waste Elimination Idea Book also involves a combination process (i.e., combining the explicit knowledge submitted by employees) (Denton, 1999). Therefore,

***H6:*** *Green knowledge combination is positively related to (a) green design, (b) green purchasing, and (c) green production process.*

Finally, *internalization* is related to the conversion of explicit knowledge into tactic knowledge. It often occurs through re-experiencing what was learned, as is often the case in learning by doing (Linderman et al., 2004). For green operation, internalization could help individuals to internalize their experiences and create green operational knowledge. For example, in Colombia's Cauca Valley Corporation, *internalization* processes such as "learning by exploration" (i.e., searching for and experimenting with new concepts and processes) resulted in effective control of the water pollution in the company's supply chain (Triana and Ortolano, 2005). Therefore,

***H7:*** *Green knowledge internalization is positively related to (a) green design, (b) green purchasing, and (c) green production process.*

## 4. Methods

### 4.1. Sample and data collection

We collected data from manufacturing firms located in four provinces in East China: Jiangsu, Shandong, Henan, and Anhui. There is a substantial difference among those provinces concerning their efforts to protect the environment. Therefore, our sample purposely includes companies located in different provinces that have different environmental protection requirements for companies.

We selected high-tech manufacturing companies as our research context because these companies' production and operations activities can significantly affect the local environment. For each of the four provinces, we randomly selected 500 firms identified as high-tech manufacturing companies by the Chinese Ministry of Science and Technology (https://www.innocom.gov.cn/). Thus, a total of 2000 firms are selected as our target sample. For each firm, an HR director was selected as the initial contact. The directors were asked to answer questions related to the company's demographic information. They were also asked to solicit a top manager in charge of environmental protection and an operations manager to answer the questionnaire. Specifically, HR managers were required to answer the questions related to their green HRM; the top managers were required to answer the questions related to green knowledge creation and diffusion, and the operations managers were required to answer the questions related to green performance.

We first contacted the potential respondents through email. After four rounds of reminders (two follow-up emails and two phone calls), we received 411 questionnaires. For each respondent, we offered a cash gift of RMB100 (Chinese currency). Among the returned questionnaires, 72 were excluded due to having too many unanswered questions or the questionnaires not being completed by the required managers. As a result, 339 valid responses were utilized for our analysis, constituting an effective response rate of 16.95%.

To compare the retained (n = 339) and excluded (n = 72) samples, we run a series of independent sample t-tests and Chi-square tests on the demographic variables of the respondents and their firms. The analysis indicates no significant differences regarding the age and gender of the respondents or the industry type, size, revenue, and ownership of their firms. To check nonresponse bias, we run a multivariate analysis of variance (MANOVA) test to compare the responses by the earliest (first 10 % to return the questionnaire) and latest (last 10 % to return the questionnaire) respondents (Rogelberg & Stanton, 2007). The analysis indicates no significant differences between the two groups. Thus, nonresponse bias is not a significant concern. We present the demographic information of the firms in Table 2.

### 4.2. Measurement and validation

Our questionnaire items are mostly adapted from previous studies (see the Appendix). Two bilingual researchers, fluent in Chinese and English, conduct a back-translation procedure on the questionnaire items to ensure conceptual equivalence (Hoskisson, Eden, Lau, & Wright, 2000; Weng et al., 2020). The questionnaire was first reviewed by three academicians whose field are related to environmental management and TQM. We added, removed, and revised some items based on their feedbacks. Next, as a pilot study, we administered the questionnaire to 25 managers from various high-tech manufacturing firms in Jiangsu province. They were also asked to make comments on the relevance and wording of the questionnaire items. Based on the pilot study results, we further revised our questionnaire items. We present the final questionnaire items in the Appendix.

We include six control variables in the current study. First, Chinese state-owned enterprises often possess more financial resources for environmental protection efforts than private companies (Wu & Ma, 2016). We thus include a dummy variable differentiating the two types of companies. Second, firm size is an essential indicator of organizational resources. Arguably, it is relatively easy for large companies to commit resources to environmental protection and green operations (Darnall et al., 2009). Therefore, we include two commonly used indicators of firm size (revenue and number of employees) to control for firm size. Third, prior studies show that internal and external pressures from stakeholders could influence organizations' environmental behaviors (Sarkis et al., 2010). We thus include stakeholder pressures as a control variable, measured by pressure from customers, governments, shareholders, employees, nongovernmental organizations, society, etc. Fourth, prior studies find that employees' in-role and extra-role green behaviors in the workplace can affect organizations' green performance (Dumont et al., 2017; Harvey et al., 2013; Paillé et al., 2014). We thus include these two types of green behaviors as control variables.

We test factor unidimensionality by running a series of confirmatory factor analyses. Our hypothesized ten-factor model consists of a green competency-enhancing sub-system, green motivation-enhancing sub-system, green opportunity-enhancing sub-system, green knowledge socialization, green knowledge externalization, green knowledge combination, green knowledge internalization, green design, green

**Table 2**
Demographic information.

| Characteristics | Frequency | Percentage ( 100 % ) |
|---|---|---|
| *Industry* | | |
| Electronic/information products | 123 | 36.3 |
| Advanced manufacturing and automation | 116 | 34.2 |
| New material manufacturing | 29 | 8.6 |
| Biology and medicine | 45 | 13.3 |
| Others | 26 | 7.7 |
| total | 339 | 100.0 |
| *Number of employees* | | |
| <100 | 33 | 9.7 |
| 101–300 | 132 | 38.9 |
| 301–1000 | 139 | 41.0 |
| >1000 | 35 | 10.3 |
| total | 339 | 100.0 |
| *Annual Revenue (in RMB)* | | |
| <10 million | 36 | 10.6 |
| 10 to 20 million | 205 | 60.5 |
| >20 million | 98 | 28.9 |
| total | 339 | 100.00 |
| *Ownership* | | |
| State-owned enterprises | 103 | 30.4 |
| Private companies | 236 | 69.6 |
| total | 339 | 100.0 |

purchasing, and green production process, fits the data well: $\chi2(620) = 714.76$, CFI = 0.99, TLI = 0.99, SRMR = 0.03. The factor loadings of the scale items are all larger than 0.6 (see the Appendix).

The proposed model performs better than alternative models in confirmatory factor analysis, including an eight-factor model in which green competency-enhancing subsystem, motivation-enhancing subsystem, and opportunity-enhancing subsystem are combined: $\chi2(637) = 769.81$, CFI = 0.98, TLI = 0.98, SRMR = 0.4; an eight-factor model in which green design, purchasing, and production process are combined: $\chi2(637) = 2076.61$, CFI = 0.85, TLI = 0.84, SRMR = 0.09; a seven-factor model in which green knowledge socialization, externalization, combination, and internalization are combined: $\chi2(644) = 2758.24$, CFI = 0.79, TLI = 0.77, SRMR = 0.07; a five-factor model in which green competency-enhancing subsystem, motivation-enhancing subsystem, and opportunity-enhancing subsystem are combined, while green knowledge socialization, externalization, combination, and internalization are combined: $\chi2(655) = 2774.69$, CFI = 0.78, TLI = 0.77, SRMR = 0.07; a three-factor model in which green competency-enhancing subsystem, motivation-enhancing subsystem, and opportunity-enhancing subsystem are combined, green knowledge socialization, externalization, combination, and internalization are combined, and green design, purchasing, production process are combined: $\chi2(662) = 4101.08$, CFI = 0.65, TLI = 0.63, SRMR = 0.11; and a one-factor model in which all the ten variable are combined: $\chi2(665) = 5222.42$, CFI = 0.54, TLI = 0.51, SRMR = 0.10.

We assess the reliability of the scales using Cronbach's alpha and composite reliability. The two indicators for all the scales are more significant than 0.7, and thus their reliability is deemed satisfactory (see the Appendix). We test the convergent validity of the constructs by calculating the average variance extracted (AVE). The Appendix shows that all the constructs have an AVE greater than 0.5, supporting their convergent validity. The square roots of the AVEs are more significant than the inner construct correlations, thus supporting the discriminant validity between constructs. The means, standard deviations, composite reliability, and correlations of the constructs are presented in Table 3.

It is important to note that collecting all the responses from one single respondent may introduce the risk of common method variance (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). However, we survey multiple respondents in each firm. It minimizes the risk of common method variance bias. To test the common method variance, we run a Harman one factor test (Podsakoff & Organ, 1986). The analysis results show that no one single factor emerges from the analysis. Furthermore, no single factor account for most of the variance in the variables. Therefore, common method variance is not a serious concern.

### 4.3. Analysis results

We test our hypotheses by using path analysis in Mplus 7. For each individual green HRM practice, we first calculate the average score of its indicators. Next, we calculate the mean of the average scores for the practices included in each sub-system for the three green HRM sub-systems. These means of average scores are used as the scores for the sub-systems in the path analysis. The mean scores of their indicators operationalize all the other multiple-item constructs.

The fit indexes suggest a satisfactory model fit: $\chi2(584) = 694.35$, CFI = 0.99, TLI = 0.99, SRMR = 0.03. The path analysis results are presented in Table 4. The green competency-enhancing sub-system positively affects the four green knowledge-creation and diffusion processes, supporting H1a–d. Similarly, the green motivation-enhancing sub-system is positively related to the four green knowledge-creation and diffusion processes, supporting H2a–d. However, the green opportunity-enhancing sub-system significantly affects only green knowledge combination and internalization, not socialization and externalization. The results support H3c and H3d but reject H3a and H3b. Green knowledge externalization and combination are positively related to the three green operational performance outcomes. The

**Table 3**
Descriptive statistics.

| | Mean | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Ownership type | 0.70 | 0.46 | | | | | | | | | | | | | | | | |
| 2. Number of employees | 1.52 | 0.81 | 0.12* | | | | | | | | | | | | | | | |
| 3. Annual Sales | 1.18 | 0.60 | −0.07 | 0.08 | | | | | | | | | | | | | | |
| 4. In-role green behaviors | 3.05 | 0.64 | −0.01 | 0.04 | 0.02 | | | | | | | | | | | | | |
| 5. Extra-role green behaviors | 3.15 | 0.65 | 0.01 | 0.03 | 0.03 | 0.55** | | | | | | | | | | | | |
| 6. Stakeholder pressures | 3.04 | 0.55 | −0.05 | 0.05 | −0.02 | −0.06 | −0.02 | | | | | | | | | | | |
| 7. Competency-enhancing sub-system | 3.23 | 0.50 | 0.03 | 0.01 | −0.02 | 0.20** | 0.09 | −0.10 | | | | | | | | | | |
| 8. Motivation -enhancing sub-system | 3.28 | 0.64 | −0.06 | −0.01 | 0.01 | 0.23** | 0.13* | −0.06 | 0.63** | | | | | | | | | |
| 9. Opportunity-enhancing sub-system | 3.27 | 0.53 | −0.05 | 0.02 | 0.04 | 0.25** | 0.13* | −0.06 | 0.69** | 0.63** | | | | | | | | |
| 10. Green socialization | 2.86 | 0.55 | −0.06 | −0.01 | −0.02 | 0.20** | 0.18** | 0.00 | 0.46** | 0.51** | 0.39** | | | | | | | |
| 11. Green externalization | 2.77 | 0.58 | −0.10 | 0.00 | 0.10 | 0.25** | 0.12* | −0.07 | 0.54** | 0.52** | 0.48** | 0.44** | | | | | | |
| 12. Green combination | 2.85 | 0.60 | −0.01 | −0.02 | 0.03 | 0.31** | 0.14** | −0.12* | 0.50** | 0.44** | 0.48** | 0.39** | 0.56** | | | | | |
| 13. Green internalization | 2.70 | 0.65 | −0.01 | 0.08 | 0.03 | 0.27** | 0.21** | −0.05 | 0.52** | 0.53** | 49** | 0.42** | 0.54** | 0.49** | | | | |
| 14. Green design | 2.79 | 0.55 | 0.00 | 0.04 | 0.00 | 0.25** | 0.17** | −0.03 | 0.49* | 0.47** | 0.39** | 0.43** | 0.51** | 0.47** | 0.49** | | | |
| 15. Green purchasing | 2.78 | 0.72 | 0.02 | 0.05 | 0.02 | 0.31** | 0.20** | −0.12* | 0.49** | 0.48** | 0.44** | 0.46** | 0.50** | 0.52** | 0.47** | 0.54** | | |
| 16. Green production process | 2.96 | 0.69 | −0.03 | −0.03 | 0.02 | 0.16** | 0.11 | −0.03 | 0.33** | 0.35** | 0.28** | 0.33** | 0.45** | 0.38** | 0.6** | 0.40** | 0.46** | |

Note: ** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).

**Table 4**
Path analysis results.

| PATHS FROM | TO | | | | | | |
|---|---|---|---|---|---|---|---|
| | Green knowledge processes | | | | Green performance | | |
| | Green socialization | Green externalization | Green combination | Green internalization | Green design | Green purchase | Green production |
| **Control variables** | | | | | | | |
| Ownership type | −0.06 | −0.10* | 0.01 | 0.01 | 0.03 | 0.07 | 0.01 |
| Number of employees | 0.00 | −0.00 | −0.02 | 0.06 | 0.02 | 0.03 | −0.03 |
| Annual Revenue | −0.02 | 0.09** | 0.03 | 0.02 | −0.02 | −0.01 | −0.01 |
| In-role green behaviors | 0.02 | 0.11** | 0.18** | 0.08* | 0.04 | 0.11* | −0.01 |
| Extra-role green behaviors | 0.09* | −0.02 | −0.03 | 0.08* | 0.03 | 0.03 | 0.02 |
| Pressures | 0.05 | −0.02 | −0.07 | −0.00 | 0.02 | −0.07 | 0.02 |
| **Green HRM subsystems** | | | | | | | |
| Competency subsystem | 0.28** | 0.38** | 0.33** | 0.30** | 0.17* | 0.12 | 0.00 |
| Motivation subsystem | 0.31** | 0.22** | 0.11* | 0.28** | 0.09 | 0.10 | 0.09 |
| Opportunity subsystem | −0.02 | 0.08 | 0.19** | 0.15* | −0.06 | 0.05 | −0.06 |
| **Green knowledge processes** | | | | | | | |
| Green socialization | | | | | 0.11** | 0.22** | 0.12 |
| Green externalization | | | | | 0.18** | 0.17** | 0.31** |
| Green combination | | | | | 0.13** | 0.24** | 0.16** |
| Green internalization | | | | | 0.13** | 0.10 | 0.11 |

Note: ** significant at the 0.01 level; * significant at the 0.05 level.

results support H5a–c and H6a–c. However, green knowledge socialization significantly affects green design and purchasing, not the green production process. It supports H4a and H4b but rejects H4c. Green knowledge internalization significantly affects only green design, but not green purchasing and production process. The results support H7a but reject H7b and H7c.

## 5. Discussion and conclusion

### 5.1. Theoretical implications

Green HRM activities and processes has been regarded as one of the key organizational practices affecting green performance. Previous studies have demonstrated that green HRM can facilitate green performance by motivating individual employees to engage in green behaviors (e.g., Dumont et al., 2017; Harvey et al., 2013; Paillé et al., 2014). Our study advances the extant literature by viewing green HRM as a TQM practice and analyzing its effects on green operational performance through the mediator of an organization-wide processes of green knowledge creation and diffusion. Overall, our study confirms the positive linkage between green HRM mechanisms and green operational performance, endorsing the TQM view that TQM practices can affect organizational performance by encouraging the creation and utilization of specific knowledge.

To date, most studies on green HRM have viewed it as a sub-system (i.e., HR aspect) of EM (e.g., Dumont et al., 2017; Renwick et al., 2013; Tang et al., 2018). However, given the overlap between TQM and EM practices, there is a call to integrate TQM and EM, thus allowing one single system to manage business processes in organizations (Karapetrovic & Willborn, 1998; Molina-Azorín et al., 2009; Wilkinson & Dale, 1999; Zeng et al., 2005). Similarly, we maintain that green HRM activities and processes can be operated as a sub-system of TQM-oriented HRM to facilitate green performance. Our findings are consistent with those of Sila (2007), which shows that HRM functions as a subsystem of TQM facilitating organizational performance. They are also consistent with findings of a number of prior studies showing that quality management practices are critical for environmental management performance (e.g., Allur et al., 2018; Teixeira et al., 2019; Wiengarten and Pagell, 2012). Especially, the path of green HRM-> green knowledge creation and diffusion-> green performance identified by the current study is consistent with the framework proposed by Abbas (2019), which suggests TQM affect environmental performance through the mediating effect of knowledge management. As such, our study takes a first step toward integrating green HRM into the broader TQM framework and investigates its performance implication from a TQM perspective.

Second, as a TQM practice, green HRM could affect organizational outcomes through the following two mechanisms: (1) encouraging the creation and utilization of green knowledge; and (2) encouraging the use of green practices and green behaviors throughout the organization (Hendricks & Singhal, 1997; Wruck & Jensen, 1994). From this perspective, many prior studies, with their sole focus on green behaviors and individual level, have largely ignored the relationship between green HRM and the organizational wide businesses processes, such as green knowledge creation and diffusion (e.g., Dumont et al., 2017; Harvey et al., 2013; Paillé et al., 2014). Our study demonstrates that the three green HRM sub-systems exert different effects on the four green knowledge-creation and diffusion processes. Thus, green HRM affects organizational outcomes by influencing employee workplace behaviors and promoting green knowledge. This is consistent with the findings of prior TQM studies that TQM practices could facilitate knowledge creation and diffusion in organizations (e.g., Colurcio, 2009; Fong et al., 2011; Ooi, 2014; Yusr et al., 2017). It is also consistent with HRM literature, which suggests that a major mechanism that HRM affect organizational outcomes is through facilitating knowledge creation and diffusion (Edvardsson, 2008; Lopez-Cabrales et al., 2009; Minbaeva et al., 2009). As such, our study identifies a critical alternative mechanism of green HRM's influence on organizational outcomes.

Specifically, our analysis shows that among the three green HRM sub-systems, the motivation-enhancing, and the competency-enhancing sub-systems affect all four green knowledge-creation and diffusion processes. However, the opportunity-enhancing system is significantly related to green combination and internalization, but not green socialization and externalization. This is probably because of the challenges that employees face during socialization and externalization processes. These processes often aim to conduct a broad and general search for green knowledge that remains unknown to the organization, presenting substantial challenges to employees. Recall that the opportunity-enhancing sub-system involves green empowerment and employee involvement. Jung et al. (2003) maintains that when employees are empowered and/or provided with the opportunity to participate in organizational decision-making, they may experience confusion because they face the challenge of assessing what needs to be done and achieving innovative outcomes. Therefore, with only opportunity-enhancing subsystem in place, employees may not be able to accomplish effective socialization and externalization.

Third, our study demonstrates that green knowledge-creation and diffusion processes affect green operational performance. Our findings are consistent with those of previous studies that effective knowledge management facilitates green performance (e.g., Abbas, 2019; Abbas and Sağsan, 2019; Shehzad et al., 2022). Specifically, green design is affected by all four green knowledge-creation and diffusion processes. However, green purchasing is affected by all processes except for green internalization. A possible reason for this insignificant relationship is that internalization is less relevant to purchasing procedures than the other three processes. Specifically, according to Monczka et al. (2016), purchasing procedures typically involve three critical processes (1) purchasing department identifies the need of internal customers. Arguably, green purchasing needs involves identifying different departments' needs for green supplies, which could be collected through the green socialization process. (2) purchasing department needs to understand the green purchasing needs of different departments (tacit knowledge) and develop a detailed description of these needs (explicit knowledge). This is an externalization process. (3) purchasing department needs to develop green requirements for suppliers (explicit knowledge) based on the descriptions of different departments' needs (explicit knowledge). This is a combination process. Thus, knowledge-creation and diffusion processes such as socialization, externalization, and combination are closely related to typical purchasing procedures and thus could significantly affect green purchasing. In contrast, green internalization process is less relevant to green purchasing than the other three processes. As a result, the effect of the internalization process is insignificant in our path analysis.

Further, the green production process is affected only by green externalization and green combination, aiming to create explicit green knowledge. The two processes that do not affect green production —green socialization and green internalization—aim to create tacit knowledge. Therefore, our findings suggest that explicit knowledge is more critical than tacit knowledge in green production. While green production involves tacit knowledge such as production skills and know-how (Triana & Ortolano, 2005), the focus of implementing green production process is often on developing a green production manual and implementing green manufacturing systems, which are principally related to developing and utilizing explicit green Knowledge (e.g., planning process, operational procedures, auditing procedures) (Liu et al., 2017; Testa et al., 2018). Therefore, it is not surprising that in our path analysis, the two processes related to explicit green knowledge explain most of the variance of green production, and the effects of the two processes aiming to create tacit green knowledge are insignificant.

Overall, our study demonstrates that different green knowledge-creation and diffusion processes exert varying effects on green operational performance. Each of the four processes involves different modes of knowledge conversion, which might be critical for some green performance outcomes but not others. As such, our findings contribute to literature by providing nuanced understanding regarding the relationship between the four green knowledge processes and different green performance outcomes.

Our study also responds to the call to connect knowledge management and HRM (Runar Edvardsson, 2008; Svetlik & Stavrou-Costea, 2007). Knowledge management focus on developing, sharing, applying knowledge within a firm to gain and sustain a competitive advantage (Runar Edvardsson, 2008). As HRM enables firms to develop new knowledge and intellectual capital, an obvious link exists between HRM and knowledge management (Kianto et al., 2017; Svetlik & Stavrou-Costea, 2007). While several studies have examined the relationship between the two systems in recent years, many of them only attempt to establish a linkage between a construct of HRM and a construct of knowledge management or intellectual capital (e.g., Kianto et al., 2017; Lei et al., 2021; Turulja and Bajgoric, 2018). In the current study, we develop and empirically test a model depicting the relationship between various green HRM sub-systems and green knowledge creation and diffusion processes, which provide a more nuanced understanding of the relationship between HRM and knowledge management.

### 5.2. Practical implications

Our study also provides important implications for practitioners. First, managers should design their EM programs, including green HRM, as a part of their overall TQM initiative. EM and TQM systems share similar HRM practices and several common implementation practices, such as leadership, planning, information and analysis, process management, and supplier management (Molina-Azorín et al., 2009). Therefore, developing and implementing EM and TQM systems separately may result in wasting organizational resources and potentially creating conflicting policies and practices. Similarly, developing and implementing green HRM and TQM-oriented HRM separately is unnecessary. We strongly encourage managers to develop and operate green HRM as a sub-system of TQM-oriented HRM. By doing so, they can simultaneously facilitate EM and TQM efforts in their organizations.

Second, it is also vital for green HRM programs to include all the seven TQM-oriented practices identified by our study. Prior researchers have proposed various green HRM practices and empirically demonstrated that these individual practices facilitate green performance (Yong et al., 2019). Our study reveals that these practices form three sub-systems, focusing on employees' green competency, motivation, and opportunities. Given that employee performance is generally determined by employees' ability, motivation, and opportunity to perform (Sterling & Boxall, 2013), a green HRM system must include all three sub-systems to facilitate green performance.

Third, our study highlights the importance of knowledge-creation and diffusion processes, which constitute critical mediators between green HRM and green operational performance. In EM, researchers and practitioners often focus on ensuring that employees conform to green operational procedures and motivating employees to engage in corporate citizenship behaviors related to EM. However, from the TQM perspective, excellent performance is achieved when relevant knowledge is well developed and diffused in organizations (Linderman et al., 2004). Therefore, HR must also pay attention to the green knowledge creation and diffusion in the organization and facilitate the four relevant processes of knowledge creation and diffusion identified in the current study.

### 5.3. Limitations and future research directions

There are several limitations of the current study that must be acknowledged. First, we collect data from one single country: China. Dumont et al. (2017) suggest that effects of green HRM practices in multinational enterprises could be subject to the influence of country of origin. Similarly, we suspect that green HRM, green knowledge creation and diffusion, and green operations practices may vary across countries, especially countries with substantial different cultural backgrounds like China versus United States. Therefore, future studies should replicate our analysis in different countries to verify our research model further.

Second, we collect our data at one point in time. This research design makes it challenging to identify the causal relationships among the study constructs. Future research should conduct longitudinal studies to explore the effects of green HRM over time fully. Especially, one may investigate, given the green HRM practices, how green knowledge creation and diffusion improve over time, and subsequently affect green performance outcomes. Third, we analyze the relationship between green HRM practices and knowledge creation and diffusion at the organizational level. It would be interesting for future research to examine these relationships at the team or departmental level. This is because these settings provide different context for green HRM. For example, team members need to work closely with each other during the green knowledge creation and diffusion processes. Therefore, the personal relationships among them could play a critical role in shaping the

effectiveness of green HRM on those processes at the team level. Therefore, future studies should explore how the specific contexts of individual teams and/or departments affect those relationships. This could shed further light on the mechanisms through which green HRM affects organizational outcomes.

## CRediT authorship contribution statement

**Zhining Wang:** Methodology, Investigation, Formal analysis, Data curation, Conceptualization, Writing - original draft, Writing - review & editing. **Shaohan Alan Cai:** Methodology, Investigation, Formal analysis, Data curation, Conceptualization, Writing - original draft, Writing - review & editing. **Shuang Ren:** Writing – review & editing, Visualization, Supervision, Conceptualization. **Sanjay Kumar Singh:** Visualization, Writing – review & editing.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix. Questionnaire items

***Green HRM*** (The items are adapted from Tang et al. (2018), unless specified otherwise)

### Green recruitment and selection (GRS)

(AVE[1] = 0.68; CR[2] = 0.86; Cronbach's Alpha = 0.85)

GRS1: We attract green job candidates who use green criteria to select organizations. (0.92)[3]

GRS 2: We use green employer branding to attract green employees. (0.72)

GRS 3: Our firm recruits employees who have green awareness. (0.82)

### Green training (GT)

(AVE = 0.65; CR = 0.85; Cronbach's Alpha = 0.83)

GT1: We develop training programs in environmental management to increase employees' environmental awareness, skills, and expertise. (0.78)

GT2: We have integrated training to create the emotional involvement of employees in environment management. (0.67)

GT3: We develop training programs that link environmental education and knowledge to behaviors to develop preventative solutions. (0.95)

### Green performance management (GPM)

(AVE = 0.74; CR = 0.92; Cronbach's Alpha = 0.91)

GPM1: We use green performance indicators in our performance management system and appraisals. (0.78)

GPM2: Our firm sets green targets, goals, and responsibilities for managers and employees. (0.80)

GPM3: In our firm, managers set objectives for achieving green outcomes, which are included in appraisals. (0.90)

GPM4: In our firm, there are dis-benefits in the performance management system for non-compliance or not meeting environment management goals. (0.94)

### Green reward (GPR)

(AVE = 0.78; CR = 0.95; Cronbach's Alpha = 0.94; adapted from Dumont et al. (2017) and Obeidat et al. (2020))

GPR1: Employees in our company are rewarded for making suggestions for improving environmental management systems. (0.81)

GPR2: Employees in our company are rewarded for making suggestions on green manufacturing, product design, and/or supplies. (0.83)

GPR3: Our company provides individual financial incentives for environmental management system improvement. (0.93)

GPR4: Our company provides individual financial incentives for green manufacturing improvement, product design, and/or supplies. (0.90)

GPR5: Employees in our company are rewarded for green workplace behaviors. (0.94)

### Green empowerment (GE)

(AVE = 0.74; CR = 0.94; Cronbach's Alpha = 0.92; adapted from Jun et al. (2006), Moraes et al. (2019), Nejati et al. (2017) and Roscoe et al. (2019))

GE1: Employees have significant autonomy in deciding how to handle environmental problems in practices. (0.90)

GE2: Employees would not be punished for unsuccessful environmental improvement ideas. (0.89)

GE3: Employees are provided with sufficient information to arrive at good environmental improvement suggestions. (0.76)

GE4: Every employee is aware of the firm's environmental policy. (0.82)

GE5: Top management encourages employee suggestions for environmental performance improvement by setting up an employee environmental suggestions scheme. (0.87)

GE6: Most employee environmental protection suggestions are implemented. (0.91)

### Green involvement (GI)

(AVE = 0.76; CR = 0.95; Cronbach's Alpha = 0.94)

GI1: Our company has a clear developmental vision to guide the employees' actions in environmental management. (0.90)

GI2: There is a mutual learning climate among employees in our firm for green behavior and awareness. (0.87)

GI3: There are several formal or informal communication channels to spread green culture in our firm. (0.82)

GI4: In our firm, employees are involved in quality improvement and problem-solving on green issues. (0.88)

GI5: We offer opportunities for employees to participate in environmental management, through means such as newsletters, suggestion schemes, problem-solving groups, low-carbon champions, and green action teams. (0.86)

GI6: Our company emphasizes a culture of environmental protection. (0.90)

### Green teams (GT)

(AVE = 0.64; CR = 0.87; Cronbach's Alpha = 0.87; adapted from Jose Chiappetta Jabbour (2011), Jun et al. (2006), Moraes et al. (2019), and Nejati et al. (2017))

GT1: We frequently use teamwork to solve environmental problems. (0.85)

GT2: Employees frequently discuss environmental problems in their team meetings. (0.84)

GT3: Environmental management teams are formed for the long run. (0.87)

GT4: We have cross-functional environmental management teams. (0.61)

***Green knowledge creation and diffusion*** (The items are adapted from Schulze & Hoegl (2008))

**Socialization (KSO)**

(AVE = 0.72; CR = 0.91; Cronbach's Alpha = 0.91)

KSO1: We spent much time in personal interaction aside from organized meetings with other team people to discuss environmental protection suggestions, ideas, or solutions. (0.79)

KSO2: We spent much time in personal interaction aside from organized meetings with people from other company departments to discuss environmental protection suggestions, ideas, or solutions. (0.83)

KSO3: We spent much time in intense discussions about environmental protection suggestions, ideas, or solutions in face-to-face meetings with people from other departments in the company. (0.87)

KSO4: We spent much time consciously creating a shared understanding of an environmental protection problem with people from other departments in the company. (0.90)

**Externalization (KE)**

(AVE = 0.63; CR = 0.87; Cronbach's Alpha = 0.86)

KE1: We spent much time reflecting collectively and framing our ideas or solutions concerning the environmental protection demands from stakeholders (government regulatory agencies, customers, shareholders, suppliers, employees, local communities, NGOs, etc.). (0.88)

KE2: We spent much time interviewing competent people inside and outside our organization about ideas or solutions concerning relevant environmental protection technologies. (0.80)

KE3: We spent much time interviewing competent people about ideas or solutions concerning environmental protection demands from stakeholders (government regulatory agencies, customers, shareholders, suppliers, employees, local communities, NGOs, etc.). (0.69)

KE4: We spent much time creating detailed descriptions (e.g., protocols, presentations, reports) containing newly developed knowledge about environmental protection demands from stakeholders (government regulatory agencies, customers, shareholders, suppliers, employees, local communities, NGOs, etc.) and relevant solutions. (0.80)

**Combination (KCB)**

(AVE = 0.67; CR = 0.89; Cronbach's Alpha = 0.89)

KCB1: We systematically edited the technical knowledge of environmental protection collected. (0.80)

KCB2: We systematically edited the knowledge collected about green demands from stakeholders (government regulatory agencies, customers, shareholders, suppliers, employees, local communities, NGOs, etc.). (0.81)

KCB3: We systematically edited the knowledge collected about the procedure of creating ideas related to green manufacturing, product design, and supply chain management. (0.79)

KCB4: We distributed our newly gained insights about stakeholders' green needs and environmental protection knowledge within the organization. (0.87)

**Internalization (KI)**

(AVE = 0.71; CR = 0.91; Cronbach's Alpha = 0.90)

KI1: We spent much time in trial-and-error (experimenting), thereby developing a sense of the feasibility of our thoughts regarding the functionality of the environmental protection technology. (0.81)

KI2: We spent much time in trial-and-error (experimenting), thereby developing a sense of the feasibility of our thoughts regarding green demands from stakeholders (government regulatory agencies, customers, shareholders, suppliers, employees, local communities, NGOs, etc.). (0.80)

KI3: We spent much time in trial-and-error (experimenting), thereby developing a sense of the feasibility of our thoughts regarding creating ideas related to green manufacturing, product design, and supply chain management. (0.84)

KI4: We spent much time systematically testing our theoretical knowledge about green demands from stakeholders (government regulatory agencies, customers, shareholders, suppliers, employees, local communities, NGOs, etc.). (0.92)

***Green operation*** (The items are adapted from Liu et al. (2017))

**Green design (GOD)**

(AVE = 0.68; CR = 0.89; Cronbach's Alpha = 0.89)

GOD1: Design of products for reduced consumption of material/energy. (0.78)

GOD2: Design products to reuse, recycle, and recover material and parts. (0.84)

GOD3: Design products to avoid or reduce the use of hazardous products and/or their manufacturing process. (0.82)

GOD4: Design of product for longevity and durability. (0.85)

**Green purchasing (GOP)**

(AVE = 0.71; CR = 0.93; Cronbach's Alpha = 0.92)

GOP1: Providing design specifications to suppliers that improve the environmental requirements for purchased items. (0.84)

GOP2: Cooperation with suppliers for environmental objectives. (0.82)

GOP3: Environmental audit for supplier's inner management. (0.84)

GOP4: Select suppliers certified by ISO 14,000 series. (0.83)

GOP5: Second-tier supplier environmentally friendly practices evaluation. (0.89)

**Green production process (GOM)**

(AVE = 0.62; CR = 0.89; Cronbach's Alpha = 0.89)

GOM1: Cross-functional cooperation for environmental improvement (0.63)

GOM2: Environmental compliance and auditing programs (0.73)

GOM3: Making efforts to obtain ISO 14,000 series certification (0.81)

GOM4: Environmental management systems exist (0.86)

GOM5: Detailed environmental management operational procedures (adapted from Sarkis et al., 2010) (0.88)

**Control variables**

*Employee in-role green behaviors (EIR)*

(AVE = 0.79; CR = 0.92; Cronbach's alpha = 0.92; adapted from *Bissing-Olson et al. (2013)*)

EIR1: Employees adequately completed assigned duties in environmentally friendly ways. (0.89)

EIR2: Employees fulfill responsibilities specified in their job descriptions in environmentally friendly ways. (0.87)

EIR3: Employees perform the tasks that are expected of them in environmentally friendly ways. (0.90)

**Employee extra-role green behaviors (EXR)**

(AVE = 0.81; CR = 0.93; Cronbach's alpha = 0.92; adapted from *Bissing-Olson et al. (2013)*)

EXR1: Employees take chances to get actively involved in environmental protection at work. (0.95)

EXR2: Employees takes the initiative to act in environmentally friendly ways at work. (0.88)

EXR3: Employees do more for the environment at work than they are expected to. (0.86)

**Stakeholder pressures (PR)**

(AVE = 0.55; CR = 0.88; Cronbach's alpha = 0.88; partially adapted from Sarkis et al. (2010))

PR1: Customer pressures (0.74)

PR2: Government pressures (0.70)

PR3: Shareholder pressures (0.82)

PR4: Employee pressures (0.77)

PR5: NGO/community pressures (0.72)

PR6: Other stakeholders' pressures (0.69)

Note: 1. AVE: Average Variance Extracted; 2. CR: Composite Reliability; 3. Factor loading

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