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Intelligent transformation of the manufacturing industry for Industry 4.0: Seizing financial benefits from supply chain relationship capital through enterprise green management

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ABSTRACT

Prior research and practices of Industry 4.0 mostly centered on the intelligent transformation of the manufacturing industry from a technical perspective. However, it remains unclear how social and environmental factors can improve companies' performance in their digital transformation under Industry 4.0. Our research addresses this gap by exploring how companies undergoing digital transformation can leverage their relationship capital and green management initiatives to improve their financial performance, benefiting the entire supply chain. Specifically, we developed a conceptual model that captures the relationship between supply chain relationship capital, enterprise green management, and financial performance and used structural equation modeling and SPSS PROCESS to empirically test the hypotheses with data collected from 308 Chinese manufacturing companies. The findings indicate that for companies in the digital transformation of Industry 4.0, supply chain relationship capital positively affects enterprise green management, which subsequently enhances financial performance. Meanwhile, supply chain relationship capital also indirectly improves companies' financial performance by leveraging their green management initiatives. Our findings contribute to the literature by enriching the implications of relational capital in supply chains and strengthening the viability of green management. We also provide practical guidance for companies to effectively implement green management programs and exploit their relationship capital.

1. Introduction

Industry 4.0 paves a solid foundation for the manufacturing industry to pursue digital operation and improve the intelligence of its whole supply chain. In an attempt to integrate digital technology into the existing manufacturing processes, digital manufacturing, i.e., the digitalization of manufacturing, emphasizes the rapid collection, analysis, planning, and reorganization of product, process, and resource information with the help of various information technologies, to facilitate product design, function simulation, and prototype manufacturing, thus quickly producing the products to meet the needs of customers.

Digital and intelligent manufacturing has become an important trend of Industry 4.0 in the global manufacturing industry. Governments worldwide have been propelling manufacturing companies to accelerate their adoptions of digital product development and smart procurement to facilitate the transformation of existing manufacturing models. For instance, the Chinese government has shown great enthusiasm and expectation for Industry 4.0 and launched many initiatives to promote its manufacturing industry's digital transformation. To benchmark Germany's Industry 4.0 initiative, China developed the Made in China 2025 strategic plan[1]. The plan strives to integrate information technology with manufacturing technology, increase the variety and volume of intelligent manufacturing equipment and products, design and deploy smart manufacturing strategies, and augment manufacturing process intelligence (Yu and Huo, 2019; Yu et al., 2019). In their responses to this strategic plan, companies have been increasingly engaged in

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[1] Related content is also available at http://www.gov.cn/zhuanti/2016/MadeinChina2025-plan/index.htm.

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intelligent transformation to upgrade their traditional practices. As a result, many smart manufacturing applications have emerged in some industry-leading companies, for instance, Huawei's Cloud, Haier's COSMOPlat Industrial Internet Platform, Gree and Geely's Intelligent Factory, Baosteel's 1580 Smart Workshop, and Hikvision's Intelligent Manufacturing Base.

Digital and green operations are complementary and inseparable in transforming the manufacturing processes. First, digital transformation can superimpose existing manufacturing practices with networking and intelligence capabilities, which is conducive to improving the flexibility and precision of manufacturing, leading to flexible, green, and smart productions. Besides this, the increased awareness of global sustainability and environmental protection has recognized digitalization as a new trend in green industrial development, i.e., digital transformation is essential in facilitating the growth of the green manufacturing industry. While intelligent manufacturing aims to transform and upgrade traditional manufacturing, green manufacturing will support the existing intelligent manufacturing model by complementing and promoting each other. Hence, manufacturing companies are actively seeking ways to implement green development to enable smart transformation and upgrading their progress towards Industry 4.0. For example, with the help of green partner certification, Huawei encourages its suppliers to implement green design and production in the process of intelligent transformation, thereby greening the supply chain operations of its products (Yu et al., 2019).

Meanwhile, green management has received widespread attention from manufacturing companies and government agencies. For instance, green manufacturing has appeared in important national documents in China, such as "Industrial Green Development Plan (2016–2020)" and "Green Manufacturing Engineering Implementation Guide (2016–2020)" (Yu and Huo, 2019; Wu et al., 2020). As of April 2020, a total of 274,809 companies in China have passed the ISO14001 environmental management system certification, accounting for approximately 43.2% of the total number of companies (Yu et al., 2020). Green production, design, recycling and reuse, packaging, and other relevant practices have become essential initiatives toward greening the supply chains in many manufacturing companies such as HP, Lenovo, and BAIC. For example, Lenovo promotes green production through innovative technologies and alternative ways of utilizing renewable energy. Lenovo also engages in green recycling by providing its customers global asset recycling services (ARS) and further harmless treatment.

A company's engagement in environmental-friendly activities manifests its active fulfillment of social responsibilities (Yu et al., 2020; Yu and Huo, 2019), thereby establishing its social reputation and right image or brand. However, due to the lack of relevant experience and management skills, green management is insufficient in most companies, nor is internal environmental management (Zhu and Sarkis, 2004). Meanwhile, prior research has not indicated if green management will bring financial benefit, and the extant findings are mostly inconsistent (Molina-Azorín et al., 2009). According to Zhu and Sarkis (2004), green management's economic impact needs to be further examined, which is one of the focuses of this research.

The social–technical system theory believes that social systems and technological systems jointly affect an enterprise's behavior and its consequent performance (Siawsh et al., 2021). Although digital manufacturing promoted by Industry 4.0 constitutes an important technological system for manufacturing transformation, it is inseparable from the collaborative promotion of social system elements to achieve better results. One of the essential social system drivers for green management is to build good relationship capital with suppliers and customers, which many companies have practiced during the implementation of digital manufacturing. For example, Sony and Huawei launched a "green partner certification system/program," Cummins initiated a "white paper of practicing green cooperation," Unilever introduced a "sustainable action plan," and China Mobile embarked on a "green action plan" (Yu and Huo, 2019). These activities are committed to maintaining an excellent cooperative relationship with suppliers or supply chain partners to establish relationship capital, thus achieving green management. Therefore, having the right supplier and customer relationship can be an essential prerequisite for implementing green management. However, extant research focusing on relationship capital is limited; how it affects green management has not reached an agreement. For instance, Yu and Huo (2019) found that supplier relationship capital enhances the positive impact of environmental orientation on supplier green management, thus implying the potential effect of relationship capital on green management. Chen and Hung (2014) suggested that relationship capital promotes environmental cooperation in knowledge sharing, leading to collaborative green innovation. Yu and Huo (2018) identified three dimensions of supply chain relationship capital: supplier, internal, and customer relationship capital. Yu et al. (2020) further indicated that internal relationship capital indirectly enhances financial performance through internal and supplier green management, while supplier and customer relationship capital improves financial performance through supplier and customer green management, respectively. However, it remains unclear if and how supplier and customer relationship capital affects internal green management. Therefore, it is essential to clarify the impact of relationship capital on green management for manufacturers undergoing digital transformation in the supply chain context.

Prior research has identified two types of inter-organizational supply chain relationship capital (supplier relationship capital and customer relationship capital) (Yu et al., 2020; Wu et al., 2020) and three types of enterprise green management practices (internal environmental management, ecological design, and investment recovery) (Zhu and Sarkis, 2004; Sarkis et al., 2010). Our study adopts these categorizations to explore how companies can financially benefit from supply chain relationship capital and enterprise green management in the transformation of digital manufacturing. Specifically, we study the following three research questions:

(1) *How does supply chain relationship capital affect enterprise green management in digital transformation under Industry 4.0?*
(2) *How does enterprise green management affect companies' financial performance in digital transformation under Industry 4.0?*
(3) *How do supply chain relationship capital and enterprise green management jointly influence companies' financial performance in digital transformation under Industry 4.0?*

Our research makes valuable contributions to the literature from the following aspects. First, we find out how supply chain relationship capital can help companies improve their financial performance through enterprise green management in digital manufacturing propelled by Industry 4.0. Second, we enhance the theoretical framework of green management by incorporating supply chain relationship capital as a driver. Third, we extend the context of relationship capital to supply chains, thereby enriching the applicable scenarios of social capital. Our findings provide practical guidance for manufacturing companies to improve financial benefits by leveraging their supply chain relationship capital and engaging in green management initiatives in the process of digital transformation under Industry 4.0.

The rest of the paper proceeds as follows. The following section outlines the theoretical background and develops the research hypotheses. Section 3 summarizes our research methodology. Section 4 presents the analysis and results. Section 5 discusses our findings and their managerial implications. The last section concludes the paper with limitations and future research directions.

2. Theoretical background and hypotheses development

2.1. Industry 4.0

Industry 4.0 is "*a structure of that relies upon the integration of the* *vertical and flat esteem chains, the digitization of administrations and items, and introduction of inventive models for business*" (Rejikumar et al., 2019; p.2515), which can be considered a policy-driven product (Reischauer, 2018). According to the strategic roadmap propose by Ghobakhloo (2018), Industry 4.0 is an integrated value creation system that follows 12 design principles and reflects 14 trends in technology. In particular, there are six dimensions and principles and four components of Industry 4.0, namely vertical networking, horizontal integration, business solution, and expanding technologies (Rejikumar et al., 2019).

2.1.1. Implementation

Prior research identified ten critical success factors of Industry 4.0 implementation (Sony and Naik, 2020). However, most of the extant studies mainly concentrated on the following three aspects: (1) drivers and barriers, (2) implementation pattern, and (3) maturity assessment. First, the antecedents of the drivers and barriers of Industry 4.0 implementation can be roughly divided into three types—technology, society, and environment—with technical factors being the primary focus. For example, the adoption of Industry 4.0 can be attributed to factors such as information technology maturity, technology incentive (Lin et al., 2018), advanced manufacturing technologies, new technologies investment (Cunha et al., 2020; Agostini and Nosella, 2019), Internet of Things (IoT) ecosystem, and big data (Rajput and Singh, 2019). Technologies that facilitate supply chain information integration (Agostini and Filippini, 2019) and supply chain collaboration and transparency (Luthra et al., 2020) are also critical driving forces. Social factors include supportive government policies (Lin et al., 2018), legislation, and public advisor systems (Stentoft et al., 2020). Environmental factors involve social-economic and business environmental considerations. The market environment in emerging or developed economy can be an example of social-economic factors (Hughes et al., 2020), while many business environmental factors also play a crucial role, such as top management support (Sony and Naik, 2020; Agostini and Filippini, 2019; Wamba and Queiroz, 2020), employee involvement (Stentoft et al., 2020), employee training (Moeuf et al., 2020) and management change (Sony and Naik, 2020).

Second, existing research on the implementation patterns of Industry 4.0 mainly focuses on the adoption of related advanced information technologies, for example, front-end technologies that encompass intelligent manufacturing, intelligent products, intelligent supply chains, and intelligent work, where smart manufacturing is the core (Frank et al., 2019). Third, evaluating the maturity of Industry 4.0 implementation is another important research topic as it helps companies grasp the current implementation level and find the direction for further improvement. Existing maturity assessment models include Bibby and Dehe's (2018) model with three main dimensions and eight attributes, Sony and Naik's (2019) framework that evaluates the readiness of Industry 4.0 implementation based on six elements, and the proposal of Wagire et al. (2020) constructed by seven dimensions and 38 indices.

2.1.2. Strategic response

Manufacturing companies have made great efforts in dealing with the challenges brought by Industry 4.0, such as business model innovation (Mariani and Borghi, 2019), innovative ecosystem (Benitez et al., 2020), value innovation (Matthyssens, 2019), global strategy (Stentoft and Rajkumar, 2020), intelligent and sustainable manufacturing (Machado et al., 2020; Jabbour et al., 2018; Kamble et al., 2020), and smart factory (Büchi et al., 2020). Prior literature has identified two significant sets of the relationship between Industry 4.0 and other related business practices.

First, many studies have found the synergistic effects of Industry 4.0 with lean management (Rosin et al., 2020), lean manufacturing (Tortorella et al., 2019; Buer et al., 2018; Mariani and Borghi, 2019), Lean Six Sigma (Yadav et al., 2020; Chiarini and Kumar, 2020), total quality management (Chiarini, 2020), thus contributing to the practice of circular economy and sustainable development (Felsberger et al., 2020; Kamble et al., 2020; Mariani and Borghi, 2019; Rosa et al., 2020). However, some studies have also found that Industry 4.0 technologies make no significant improvement in environmental sustainability (Chiarini et al., 2020).

Second, prior studies suggested that Industry 4.0 facilitates many aspects of supply chain management, including its innovation (Hahn, 2020), digitalization (Wamba and Queiroz, 2020), sustainability diffusion (Luthra et al., 2020), version 4.0 (Ghadge et al., 2020), resilience (Ralston and Blackhurst, 2020), ripple effect and risk control (Ivanov et al., 2019) and lean management (Núñez-Merino et al., 2020).

2.1.3. Performance implication

Prior studies have investigated how Industry 4.0 affects various types of performance, including operational, supply chain, sustainable, and industrial performance. However, a consensus has not been reached. For instance, some studies reported that Industry 4.0 technologies could directly improve operational performance, e.g., Szalavetz (2019), Cavallone and Palumbo (2020), Gillani et al. (2020) and Kamble et al. (2020). In contrast, Dalenogare et al. (2018) suggested that although some emerging technologies contribute to the improvement of industrial performance, others do not. Büchi et al. (2020) indicated that only micro-level local units gain better performance from opportunities presented by Industry 4.0. Furthermore, most prior studies focus on Industry 4.0's indirect effects on organizational performance through the mediating role of various factors such as employee involvement (Tortorella et al., 2021), digital supply chain platform (Li et al., 2020), supply chain integration, information sharing (Fatorachian and Kazemi, 2020), lean manufacturing practices (Kamble et al., 2020), dynamic capabilities (Felsberger et al., 2020) and behavior and strategy of companies (Grandinetti et al., 2020).

In summary, existing research on Industry 4.0 follows the logic of antecedents–practice–response–performance, in which technical factors have always been the focus. In terms of antecedents, the current emphasis is mainly on the technical level. In contrast, the impacts of social and environmental factors are insufficiently studied, which is the focus of our study. The practice of Industry 4.0 mostly centers on the adoption of relevant advanced information technologies, while the strategic response to Industry 4.0 addresses the digital and intelligent transformation facilitated by these technologies for companies and their supply chains. Due to the enormous investment of Industry 4.0 in its early stage of adoption, it remains unclear whether and how Industry 4.0 can improve organizations' financial performance. Against this backdrop, we summarize the current theoretical research framework of Industry 4.0 in Fig. 1.

From a theoretical perspective, the social-technical system theory implies that social system elements such as supply chain relationship capital may create synergistic effects for adopting and implementing the digital manufacturing technology system. At the same time, according to the resource-based theory, valuable resources possessed by enterprises help them develop unique capabilities, thus facilitating the creation of sustainable competitive advantages (Barney, 1991). The social capital theory and relational view consider an enterprise's heterogeneous relationship with its upstream and downstream partners a valuable resource (Yu et al., 2020; Yu and Huo, 2018; 2017; Dyer and Singh, 1998; Kale et al., 2000). Meanwhile, the organizational capability theory considers green management a unique capability for an enterprise (Huo et al., 2014; Yu et al., 2019,2020; Yu and Huo, 2019). Therefore, the logic of resources–capabilities–consequences embedded in the existing theories allows us to propose the theoretical, conceptual model shown in Fig. 2 to further investigate the role of social system elements (i.e., supply chain relationship capital) in complementing the technology system elements of digital manufacturing promoted by Industry 4.0.

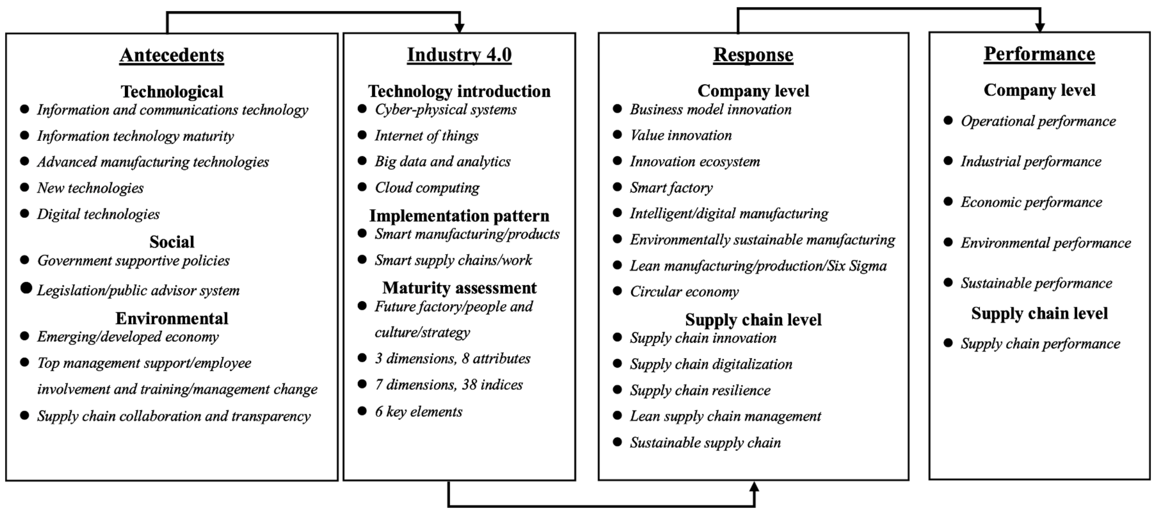

Fig. 1. Theoretical framework of current research on Industry 4.0.

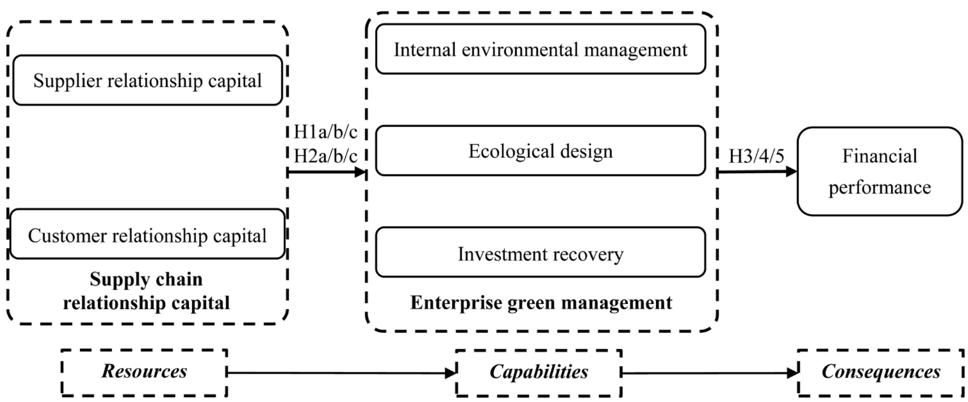

Fig. 2. Conceptual model.

2.2. Impact of supply chain relationship capital on enterprise green management

2.2.1. Supplier relationship capital and enterprise green management

Supplier relationship capital can be defined as "*trust, obligations, respect, and friendship that the core company has developed with its major suppliers through a history of interactions*" (Villena et al., 2011; p.563). Industry 4.0 technologies facilitate communication between manufacturers and suppliers. Establishing a friendly relationship with suppliers based on mutual benefit, trust, and respect provide a strong guarantee for total environmental quality management within a manufacturer from its sources. Manufacturers will, therefore, actively comply with environmental regulations and audit procedures, carry out environmental management according to ISO14001 standards, and achieve ecological improvement by seeking the support of top management and cross-functional cooperation between various departments. Meanwhile, the supplier's green input (e.g., the accurate information of the relevant materials' performance and component parameters) can help manufacturers avoid using toxic and harmful materials and manufacturing processes that seriously affect the environment. Such input also allows manufacturers to reconsider recycling or repairing products, parts, or materials during research and design. All these potential outcomes are conducive to controlling manufacturers' excess inventory or materials and reducing the sale of waste materials and idle equipment assets.

Most scholars have confirmed the positive relationship between supplier relationship and enterprise green management. Sustaining a good supplier relationship is beneficial for environmental procurement activities, including resource conservation, reuse, and recycling (Carter and Carter, 1998), pollution prevention (McEvily and Marcus, 2005), ecological design (Wu et al., 2012), and environmentally sustainable production and logistics practices. Therefore, more and more world-renowned multinational companies are keen on carrying out win–win cooperation with suppliers, in which collaboration in environmental protection is one of their important initiatives. Yu et al. (2020) suggested that supplier relationship capital facilitates enterprise green management. Thus, we propose:

> *H1a: Supplier relationship capital positively affects a manufacturing company's internal environmental management in its digital transformation under Industry 4.0.*
> *H1b: Supplier relationship capital positively affects a manufacturing company's ecological design in its digital transformation under Industry 4.0.*
> *H1c: Supplier relationship capital positively affects a manufacturing company's investment recovery in its digital transformation under Industry 4.0.*

2.2.2. Customer relationship capital and enterprise green management

Customer relationship capital can be defined as "*trust, obligations, respect, and friendship that the core company has developed with its major customers through a history of interactions*" (Villena et al., 2011; p.563). Industry 4.0 technologies also promote the interaction between manufacturers and customers. According to the scope of the application of ISO14001, it is one of the starting points for companies to establish environmental management systems to confirm compliance by relevant parties, including customers. Therefore, customers' friendly trust relationship will prompt companies to consciously abide by relevant environmental regulations and audit procedures and actively carry out ISO14001 certification. The senior management's commitment, the support of middle managers, and the cross-functional cooperation between different departments effectively motivate all the staff to participate in environmental management to gain customers' recognition of a company and its products. Meanwhile, customers' feedback on their individual experience and environmental impact can be an important reference for environmental protection design. It can help companies mitigate the negative environmental impact throughout the entire life cycle by reducing the use of raw materials and energy, recycling products or parts with repairing materials, using environmental-friendly materials and parts, and designing the production process that minimizes waste. Moreover, establishing a partnership with customers is conducive to timely recycling of used, obsolete, or defective products and their packaging, finding suitable sales channels for the products, stocks, or materials, and identifying waste materials and idle equipment assets that can be reused, thereby improving the efficiency of resource use and accelerating the return of funds.

Prior research found that strengthening coordination with downstream supply chain members (including retailers) facilitates environmental procurement activities (resource conservation, reuse, recycling) (Carter and Carter, 1998). Establishing good relationships with major buyers, customers, and retailers or brand owners can promote ecological design (Wu et al., 2012). Besides, Yu et al. (2020) also indicated that customer relationship capital could facilitate enterprise green management. Thus, we propose:

H2a: Customer relationship capital positively affects a manufacturing company's internal environmental management in its digital transformation under Industry 4.0.

H2b: Customer relationship capital positively affects a manufacturing company's ecological design in its digital transformation under Industry 4.0.

H2c: Customer relationship capital positively affects a manufacturing company's investment recovery in its digital transformation under Industry 4.0.

2.3. Enterprise green management and financial performance

The natural resource-based view points out if companies can use or protect natural resources in production and operation, they can also achieve high performance for the characteristics of causality or social complexity of this ability (Wong et al., 2012). The organizational capability view also indicates that green management can help companies gain a sustainable competitive advantage as an internal capability. Klassen and McLaughlin (1996) found that the higher a company's environmental management level (obtaining environmental performance awards), the more significant its positive return (stock market performance). Yang et al. (2013) also suggested that carrying out enterprise green practices can increase profits. Meanwhile, the advanced information technologies of Industry 4.0, such as flexible manufacturing and lean production, have laid a solid foundation for manufacturers to implement green management.

2.3.1. Internal environmental management and financial performance

As an organization's dynamic capability, internal environmental management can improve companies' performance. Support from the top and middle managers is critical for implementing green supply chain management (Zhu and Sarkis, 2004). Top management's primary responsibility is to clarify the direction of business development through strategic leadership, including the definition of values, vision, and strategic intent, striving to maximize the wealth of shareholders. Therefore, top management's commitment fundamentally reflects the critical value of green management strategy to shareholders' returns. With the support of middle-level managers, different functional departments cooperate in carrying out comprehensive environmental quality management through collaborations, which can mitigate the negative environmental impacts of business operations, reduce environmental risks, promote green development, and improve a company's profitability. As one of the important ways to achieve the environmental rule of law, the environmental audit can ensure that companies' production and operation comply with environmental regulations, thereby improving financial income through effectively reducing pollution and subsequent environmental costs. The introduction of ISO14000 can provide a standard measure to reduce the ecological impact (Wiengarten et al., 2013). Integrating ISO14001 standards into the daily operation will help a company standardize environmental issues through benchmarking and decreasing energy consumption, thereby shaping and enhancing companies' reputations and improving their market competitiveness (Castka and Prajogo, 2013; Link and Naveh, 2006). Meanwhile, the role of a formal ISO14001 environmental management system on companies far exceeds that of pollution control. Melnyk et al. (2003) suggested that the implementation of environmental management system certification positively affects companies' performance and significantly influences the choice and use of environmental protection activities over time.

Empirically, Klassen and McLaughlin (1996) indicated that the higher a company's environmental management level (e.g., obtaining environmental performance awards), the more significant its positive return (stock market performance). Lo et al. (2012) found that ISO14000 will help companies improve cost efficiency and profitability. Agan et al. (2013) suggested that waste treatment and environmental management systems can improve long- and short-term returns and market share. Burgos-Jiménez et al. (2013) showed that active environmental protection strategic positioning could enhance mid-term financial performance. Sambasivan et al. (2013), Sen et al. (2015), and Lucas and Noordewier (2016) claimed that environmental proactivity is positively related to financial performance. Miroshnychenko et al. (2017) demonstrated that internal pollution prevention is an important environmental driver of financial performance. Choi et al. (2018) identified the marketing benefits brought by implementing internal environmental management. Meanwhile, some studies have suggested that implementing internal green management helps improve financial performance, such as Yang et al. (2013), Yu et al. (2020), and Zaid et al. (2018). Thus, we propose:

H3: Internal environmental management positively affects a manufacturing company's financial performance in its digital transformation under Industry 4.0.

2.3.2. Ecological design and financial performance

As an evolutionary environmental strategy, an active ecological approach can achieve the desired effect of pollution prevention at an early stage (Menguc et al., 2010). Thus, setting clear environmental goals rather than controlling pollution through high terminal investment afterward is advocated for pollution reduction. As the most effective tool for implementing active environmental protection strategies, ecological design can help companies gain a competitive advantage (Hart, 1995).

Ecological design is committed to eliminating or minimizing the negative impact of products and manufacturing processes on the environment following standards in function, cost, performance, quality, and technology. Most of the environmental impacts of products during production, consumption, and disposal are directly related to the decisions in the design stage, while the ecological design is throughout the whole supply chain processes, therefore having a great significance (Handfield et al., 2001). For instance, reducing the use of materials and parts and promoting the reuse, recycling, or repair of products or components in product design can help companies save costs and increase economic benefits. Furthermore, decreasing the use of materials or processes that severely affect the environment and introducing a production process that minimizes design waste both help mitigate the negative environmental impacts, thereby establishing a company's green image and increasing its market share. Therefore, ecological design can become a systematic method to help companies address negative environmental impacts while reducing costs and promoting sales (Hu and Hsu, 2010). In a society advocating the concept of green environmental protection, ecological design can enable companies to fulfill their environmental protection responsibilities and enhance their ecological image to increase product sales and profits.

Kassinis and Soteriou (2003) showed that energy-saving and water-saving measures could improve customer satisfaction and loyalty, thereby increasing market performance. Chien and Shih (2007) suggested that green manufacturing enhances a company's financial performance. Montabon et al. (2007) indicated that actively reducing waste, remanufacturing, and environmental design have a significantly positive relationship with sales growth. Wong et al. (2012) found that product and process stewardship positively correlates with a company's financial performance. Agan et al. (2013) argued that environmental design could improve a company's long- and short-term returns and market share. Mitra and Datta (2014) claimed that environmentally sustainable production and logistics practices could improve companies' economic performance through increasing market share, opening new markets, winning new customers, accelerating organizational growth, and enhancing company image. Choi and Hwang (2015) contended that ecological design could enhance a company's financial performance. Meanwhile, Zaid et al. (2018) and Yu et al. (2020) demonstrated that internal green management could improve a company's financial performance. Thus, we propose:

H4: Ecological design positively affects a manufacturing company's financial performance in its digital transformation under Industry 4.0.

2.3.3. Investment recovery and financial performance

As a traditional form of green practice, investment recovery can reduce wastes by disposal methods and prolong the life cycle through product or material recovery (Zhu and Sarkis, 2004). It may take the form of recycling, remanufacturing, restoration, and repair to maximize the economic and ecological value of the waste products or materials before they are finally disposed of to reduce waste. Therefore, investment recovery can help companies gain competitive advantages (Ye et al., 2013; Lai et al., 2013). Specifically, investment recovery allows companies to effectively reduce the costs of raw materials and compliance responsibility, win new customers, and increase income to improve profitability (Prahinski and Kocabasoglu, 2006). Some companies even find that remanufactured products have a higher profit margin than original products (Stock et al., 2002). Investment recovery practices by recycling materials, saving energy, and reducing waste can effectively improve an industry's environmental impact (Guide et al., 2000; Ye et al., 2013). However, there are only a few empirical studies supporting this view. Among them, some studies have found that when companies invest in product renovations, the toxic gas emissions of factories will also decrease. At the same time, such practical activities can not only help companies reduce waste and environmental pollution but also allow them to lower operating costs and improve customer loyalty (Lai et al., 2013; Stock et al., 2002; Thierry et al., 1995; Ye et al., 2013). Essentially, implementing investment recovery through the collection and reprocessing of products or materials and later re-allocation to customers enables a closed-loop supply chain (Lai et al., 2013). Recycling materials from returned products means that the frequency of product disposal is reduced, which brings higher economic benefits to companies and realizes the social benefits of environmental protection (Lai et al., 2013).

Recycling practices help improve customer satisfaction and loyalty, increasing companies' market performance (Kassinis and Soteriou, 2003). Rao and Holt (2005) indicated that green outbound practices such as environmental-friendly waste management, packaging recycling, and used or end-of-life product recovery enhance a company's economic performance, including profit margin, sales, and market share. Montabon et al. (2007) suggested that recycling has a significantly positive correlation with a company's return on investment and sales growth. Ramírez (2012) found that proper management of reverse logistics activities can improve a company's financial performance and Chan et al. (2012) claimed a similar role of investment recovery. Ramírez (2012) demonstrated that reverse logistics activities positively correlate with reverse logistics costs and recycled materials value. Agan et al. (2013) argued that waste treatment could improve a company's long-term and short-term earnings and market share. Lai et al. (2013) indicated that recycling logistics practices can bring substantial financial benefits to Chinese manufacturing companies. Recycling, reprocessing, material recycling, reuse, and recycling logistics design contribute to better financial performance for companies. Yu et al. (2020) also found that enterprise green management could enhance companies' financial performance. Thus, we propose:

H5: Investment recovery positively affects a manufacturing company's financial performance in its digital transformation under Industry 4.0.

2.4. Controls

There are two control variables considered in this study. First, larger companies often have more opportunities to build supply chain partnerships and implement green management because of resource advantages (Geng et al., 2017; Yu and Huo, 2019). Meanwhile, although greening is the common pursuit of all companies, there still exist differences in companies' urgency and motivation in different industries to implement green management, thus resulting in differences in financial performance (Geng et al., 2017). For example, it is more pressing for the food, beverage, and medical industries to implement green management than the metallurgical, mechanical, and engineering industries. Likewise, the electronics and electrical industries may be more motivated to implement green management than the chemicals, textiles, and apparel industries. Eventually, there will be considerable differences in the earnings of these companies.

3. Research method

3.1. Sample selection and data collection

Our research data was collected in China, focusing on manufacturing industries. Due to the broad geographic scope and noticeable regional differences in China, Zhejiang province was selected as the target area. First, known for its booming private economy, Zhejiang has a solid manufacturing base, a complete range of industry categories, and superior scientific and technological strength. At present, Zhejiang's manufacturing industry is at the forefront of the country with its *Zhejiang Manufacturing* brand. Second, Zhejiang Province has been making great efforts to upgrade its traditional manufacturing industry with intelligent, informational, and digital transformation to accelerate the construction of a globally advanced manufacturing base in the context of Industry 4.0. Recent government policies, such as "*Zhejiang Province Smart Manufacturing Action Plan (2018–2020)*" and "*Five*-Year *Doubling Plan for Zhejiang's Digital Economy,*" have been successively promulgated to promote digitization and intelligence of industries and companies. In this context, the practical level of Industry 4.0 in Zhejiang's manufacturing sector has reached a relatively higher level. In 2019, the core industries of Zhejiang's digital economy achieved an added value of 622.894 billion yuan, representing a year-on-year increase of 14.5% (www.xinhuanet.com). In the first three quarters of 2020, the added value of Zhejiang's digital economy core industries was 489.39 billion yuan, accounting for 10.7% of its GDP. The new generation of the information technology industry achieved an added value of 76.36 billion yuan with a year-on-year increase of 20.9%, contributing to 45.2% of the province's strategic emerging industries (www.gov.cn). Third, Zhejiang has been encouraging the implementation of green manufacturing projects to accelerate its industrial development. For example, according to "*Implementation Plan for Green Manufacturing System Construction in Zhejiang Province (2018–2020)*," a total of 100 green factories and ten green parks will be cultivated and created by 2020. Fourth, Zhejiang's economy is highly outward-oriented; many manufacturing companies in Zhejiang Province have become important nodes in the global supply chain, inseparable from their supply chain partners. Therefore, it is essential for Zhejiang's manufacturing companies to participate and collaborate in global supply chains to survive in international competitions. In summary, Zhejiang is an ideal setting for conducting a questionnaire survey for studying our research questions.

We mainly collected data using postal questionnaire surveys. First of all, the sampling pool was randomly constructed from the Yellow Pages of China Telecom and Directory of Industrial and Commercial companies in Zhejiang Province. Then we contacted the target companies by phone to confirm their willingness. When a company was willing to participate, we mailed the questionnaire to their key informants with a letter explaining the purpose. We selected top and middle managers as target respondents to ensure the validity of the data. According to Frohlich (2002), we contacted the respondents by phone or email before and after the questionnaire was issued to improve the recovery rate.

A total of 450 questionnaires were distributed, and 340 were received, 32 of which were invalid. Finally, 308 valid questionnaires were used for subsequent analysis. According to Table 1, the responding companies were mainly from five major industries. More than 91% have been operating locally for more than five years. All have more than 100 employees. More than 98% have sales of more than 10 million. Table 2 shows that middle and senior managers and those who worked in existing positions for more than three years respectively accounted for 97.4 and 84.4%. Thus, the validity and authenticity of the questionnaire data can be well guaranteed.

3.2. Questionnaire and measurement

All original measurement items were chosen from the mature scales of authoritative journals. The questionnaire was formatted by a strict back-translation process, which invited three researchers with a doctorate in operations management to complete it together. The first researcher translated the English questionnaire into Chinese. Then, the second researcher translated the Chinese version back into English. Finally, the third researcher compared the back-translated questionnaire with the original one. Three researchers discussed and reconciled the differences and ambiguities of the questionnaire together. The above process was repeated until the two versions of the questionnaire's expression and meaning were consistent. Meanwhile, we conducted the pre- and pilot-tests to further modify the items repeatedly before formal large-scale distribution. The final multiple-item measurement scales can be seen in Appendix A.

Table 1
Characteristics of sample companies.

Industry type	%	Number of employees	%
Building materials, rubber, and plastics	16.9	100–199	18.8
Chemicals, textiles, and apparel	15.6	200–499	36.7
Electronics and electrical	17.5	500–999	21.8
Food, beverage, and medical	17.5	1,000–4,999	16.9
Metal, mechanical, and engineering	32.5	5,000 or more	5.8
Local operating time		**Annual sales**	
1–5 years	8.4	5–10 million	1.3
6–10 years	24.7	10–20 million	11.7
11–15 years	23.7	20–50 million	18.8
16–20 years	20.5	50 million–1 billion	24.0
21–30 years	14.3	1 billion or more	44.2
31 years or more	8.4		

Table 2
Respondent profile.

Current job position	%	Years in current job position	%
Top manager	37.6	1–3 years	15.6
Middle manager	59.8	4–6 years	34.4
Other	2.6	7–12 years	36.4
		More than 12 years	13.6

Note: Top managers mainly include chairman, general manager or chief executive officer, and deputy general manager. Middle managers include the managers responsible for operations management, environmental management, system management, supply chain management, supplier and customer relationship management, and other related functions.

Supplier–customer relationship capital was measured from the aspects of interaction, trust, respect, friendship, and mutually beneficial relationships between the focal company and their major suppliers or customers using five items, respectively, in accordance with Carey et al. (2011) and Villena et al. (2011). Following Sarkis et al. (2010), Zhu and Sarkis (2004), and Zhu et al. (2013), internal environmental management was measured from the aspects of top management support, cross-departmental coordination, and total environmental quality management using seven items. The ecological design was calculated from the aspects of saving materials and energy, reducing the use of harmful materials or manufacturing processes that seriously affect the environment, and optimizing the production process using seven items. Investment recovery was measured from the aspects of the disposal of excess inventory or materials, utilization of idle equipment assets, and elimination and disposal of obsolete and defective products using five items. Based on Flynn et al. (2010) and Huo (2012), we used five items to measure financial performance. Meanwhile, the information of two control variables was also collected from the questionnaire. Company size was measured by the total number of employees using a 5-point Likert scale with *1* representing 100–199 and *5* representing 5000 or more; industry type was measured by four dummy variables representing five industries (see Table 1).

4. Analysis and results

4.1. Nonresponse bias and common method bias test

We conducted a *t*-test to examine the impact of nonresponse bias by comparing the mean difference of characteristic variables of the questionnaires received in different stages following the principle proposed by Armstrong and Overton (1977). The results show that the mean difference of operating time, annual sales, company size, and other characteristics variables are insignificant for early and later respondents. Therefore, nonresponse bias is not serious in this study.

The impact of common method bias (CMB) was examined in the following two steps. Firstly, we conducted exploratory factor analysis (EFA). According to Table 3, six factors were extracted based on eigenvalues above one and cumulatively explained 68.835% of the variance, with the most considerable factor explaining only 15.915%. Thus, CMS was not serious (Flynn et al., 2010). Secondly, Harmon's single-factor model, six-factor model, and seven-factor model were further run sequentially by confirmatory factor analysis (CFA) (Flynn et al., 2010; Podsakoff et al., 2003; Podsakoff and Organ, 1986). For the single-factor model with only one factor loaded by all items, the fitting indicators, $\chi^2(527) = 4057.679$, NNFI = 0.443, CFI = 0.477, RMSEA = 0.148, and SRMR = 0.1299, all worse than the threshold; thus, the single-factor model should be rejected. Meanwhile, for the seven-factor model by adding a method factor that linked to all other items, there was no significant improvement of the fitting indicators: $\chi^2(505) = 572.633$, NNFI = 0.989, CFI = 0.990, RMSEA = 0.021, and SRMR = 0.0368, while

Table 3
Results of EFA.

Item	Factor loading Ecological design	Customer relationship capital	Internal environmental management	Financial performance	Investment recovery	Supplier relationship capital
SuRC1	0.091	0.118	0.113	0.087	0.081	0.817
SuRC2	0.114	0.119	0.190	-0.008	0.091	0.699
SuRC3	0.260	0.048	0.190	0.102	0.091	0.697
SuRC4	0.055	0.130	0.181	0.026	0.129	0.723
SuRC5	0.196	0.085	0.064	0.007	0.097	0.723
CuRC1	0.156	0.854	0.263	0.096	0.111	0.099
CuRC2	0.164	0.874	0.201	0.115	0.134	0.107
CuRC3	0.153	0.880	0.207	0.067	0.106	0.147
CuRC4	0.126	0.873	0.245	0.115	0.122	0.162
CuRC5	0.140	0.832	0.297	0.183	0.134	0.112
InEM1	0.031	0.278	0.639	0.141	0.097	0.130
InEM2	0.125	0.190	0.656	0.191	0.081	0.182
InEM3	0.125	0.199	0.649	0.180	0.128	0.161
InEM4	0.125	0.097	0.740	0.176	0.053	0.153
InEM5	0.119	0.173	0.721	0.094	0.167	0.203
InEM6	0.193	0.127	0.689	0.146	0.081	0.053
InEM7	0.098	0.194	0.765	0.154	0.125	0.066
EcoD1	0.732	0.122	0.058	0.223	0.058	0.118
EcoD2	0.823	0.079	0.119	0.117	0.102	0.135
EcoD3	0.781	0.108	0.136	0.165	0.100	0.128
EcoD4	0.742	0.135	0.162	0.162	0.120	0.131
EcoD5	0.755	0.113	0.124	0.040	0.134	0.130
EcoD6	0.807	0.069	0.095	0.095	0.114	0.063
EcoD7	0.739	0.107	0.098	0.096	0.161	0.118
InvR1	0.194	0.204	0.228	0.231	0.617	0.175
InvR2	0.146	0.109	0.061	0.090	0.805	0.113
InvR3	0.114	0.044	0.058	0.138	0.812	0.072
InvR4	0.103	0.052	0.165	0.084	0.802	0.080
InvR5	0.196	0.197	0.164	0.126	0.727	0.135
FinP1	0.204	0.171	0.201	0.793	0.117	0.004
FinP2	0.111	0.077	0.200	0.839	0.143	0.075
FinP3	0.170	0.105	0.202	0.823	0.103	0.050
FinP4	0.180	0.030	0.152	0.820	0.137	0.062
FinP5	0.161	0.148	0.215	0.794	0.137	0.026
Eigenvalues	4.752	4.268	4.210	3.821	3.248	3.104
Cumulative variance explained (%)	13.978	26.531	38.913	50.153	59.706	68.835

comparing them to those of the six-factor baseline model (i.e., NNFI by 0.008, CFI by 0.008, RMSEA by 0.007, SRMR by 0.008). Thus, the six-factor baseline model is more robust than the seven-factor model. Therefore, CMB will not seriously affect the following analysis.

4.2. Reliability and validity test

There are two indices, named Cronbach's alpha (alpha) and composite reliability (CR), for evaluating scale reliability. According to Table 4, the values of alpha and CR were all above the threshold of 0.8 proposed by Fornell and Larcker (1981), thus indicating good reliability.

We assessed three kinds of validity in this study. First, all measurement items were adapted from the extant mature scale published in authoritative literature, thus guaranteeing good content validity (Flynn et al., 2010). Second, we conducted CFA to assess convergent and discriminant validity, according to Fornell and Larcker (1981) and O'Leary-Kelly and Vokurka (1998). The fitting indicators, $\chi^2(512) = 631.567$, NNFI = 0.981, CFI = 0.982, RMSEA = 0.028, and SRMR = 0.0448, all exceeded the threshold proposed by Hu and Bentler (1999), thus accepting the CFA model. According to Table 4, all factor loadings were greater than 0.5, and the corresponding *t* values were also greater than 2, while the CR values were all greater than 0.7, and the average variance extracted (AVE) values were all greater than 0.5. Therefore, the scale has good convergent validity, according to Fornell and Larcker (1981). Meanwhile, the square root of AVE values on the diagonal in Table 5 were all greater than all remaining correlation coefficients, which shows that the scale has good discriminate validity, according to Fornell and Larcker (1981).

4.3. Hypothesis test and main results

We used structural equation modeling (SEM) for hypothesis testing with Amos 21. The fitting indicators, $\chi^2(690) = 986.535$, NNFI = 0.954, CFI = 0.957, RMSEA = 0.037 and SRMR = 0.0626, can be accepted. The SEM results were shown in Fig. 3. According to Fig. 3, the standardized path coefficients between supplier relationship capital and three kinds of enterprise green management were 0.329, 0.354, and 0.314, respectively, all significant at 0.001. Therefore, H1a, H1b, and H1c are supported. The standardized path coefficients between customer relationship capital and three kinds of enterprise green management were 0.460, 0.247, and 0.283, respectively, all significant at 0.001. Therefore, H2a, H2b, and H2c are supported. The standardized path coefficients between three kinds of enterprise green management and financial performance were 0.421, 0.264, and 0.204, respectively, significant at 0.001, 0.001, and 0.01. Therefore, H3, H4, and H5 are supported.

Meanwhile, the company size's standardized path coefficient on financial performance was 0.129 and only significant at 0.05. The four industries' standardized path coefficients on financial performance were 0.007, 0.005, -0.024, and -0.006, respectively, all insignificant. Therefore, the size only has a weak influence on financial performance, and different industries have no significant effect on financial performance.

Table 4
Results of CFA.

Item	Loading	t-values	Alpha	CR	AVE
Supplier relationship capital			0.834	0.836	0.505
SuRC1	0.790	—			
SuRC2	0.677	11.493			
SuRC3	0.712	12.184			
SuRC4	0.694	11.866			
SuRC5	0.674	11.459			
Customer relationship capital			0.963	0.963	0.839
CuRC1	0.905	—			
CuRC2	0.914	26.375			
CuRC3	0.917	26.561			
CuRC4	0.935	28.282			
CuRC5	0.908	25.561			
Internal environmental management			0.879	0.881	0.515
InEM1	0.671	—			
InEM2	0.701	10.899			
InEM3	0.702	10.880			
InEM4	0.735	11.355			
InEM5	0.758	11.697			
InEM6	0.672	10.558			
InEM7	0.778	11.962			
Ecological design			0.914	0.914	0.603
EcoD1	0.736	—			
EcoD2	0.836	14.582			
EcoD3	0.804	14.000			
EcoD4	0.781	13.662			
EcoD5	0.744	12.854			
EcoD6	0.788	13.716			
EcoD7	0.743	12.949			
Investment recovery			0.869	0.870	0.572
InvR1	0.720	—			
InvR2	0.769	12.567			
InvR3	0.750	12.266			
InvR4	0.763	12.383			
InvR5	0.777	12.652			
Financial performance			0.920	0.921	0.699
FinP1	0.830	—			
FinP2	0.850	18.148			
FinP3	0.856	18.113			
FinP4	0.819	17.045			
FinP5	0.825	17.254			

5. Discussion and managerial implications

5.1. Supply chain relationship capital in promoting enterprise green management

First, supply chain relationship capital positively affects enterprise green management, thus enriching the findings of Wu et al. (2012), (2020) and Yu et al. (2020). On the one hand, as the "source" of the whole supply chain, establishing partnerships with suppliers is an inevitable requirement for companies to develop environmental management systems. The green and environmental-friendly inputs provided by suppliers help manufacturers prevent the use of harmful materials in the research and design stage and facilitate the recycling of excess inventory or materials. On the other hand, interacting and communicating with customers can provide companies with timely information on market environmental standards and products' environmental requirements. To meet customer needs, companies will carry out total environmental quality management activities, design production processes with minimal waste, and establish recycling systems for used or defective products through cross-functional cooperation. Also, companies will ask for help from upstream suppliers to procure environmental-friendly materials or products from the source by providing suppliers with specific environmental requirements based on the essential qualifications and internal environmental management audits.

Second, two kinds of supply chain relationship capital have differentiated influences on enterprise green management. According to Fig. 2, two types of supply chain relationship capital have different effects on three kinds of enterprise green management. For supplier relationship capital, there are few differences among its impact on three types of enterprise green management, with the most significant impact on ecological design and the least impact on investment recovery. For customer relationship capital, its effect on the three types of enterprise green management varies greatly, with the most significant impact on internal environmental management and the least impact on ecological design. In terms of internal environmental management, the effect of customer relationship capital is more significant than that of supplier relationship capital. For ecological design and investment recovery, supplier relationship capital impacts are all larger than customer relationship capital.

5.2. Enterprise green management in improving financial performance

First, enterprise green management positively affects financial performance. ISO14001 environmental system and cross-functional cooperation create a total environmental quality management atmosphere. This helps companies simultaneously consider product life cycle characteristics, excess inventory or materials, and waste or defective products recycling from the planning and design stage, thus greening the "process" and decreasing the subsequent repairs and other processing costs. Moreover, companies can better understand materials and products' attributes through recycling, guiding their subsequent material procurement and product design. Therefore, the development of investment recovery will promote green procurement and ecological design for companies to obtain financial benefits. In summary, "green input" will eventually facilitate the production of "green products"

Table 5
Descriptive statistics of variables.

Variable	SuRC	CuRC	InEM	EcoD	InvR	FinP
Supplier relationship capital (SuRC)	0.711					
Customer relationship capital (CuRC)	0.349***	0.916				
Internal environmental management (InEM)	0.428***	0.541***	0.718			
Ecological design (EcoD)	0.383***	0.361***	0.378***	0.777		
Investment recovery (InvR)	0.342***	0.366***	0.396***	0.391***	0.756	
Financial performance (FinP)	0.212***	0.340***	0.476***	0.400***	0.382***	0.836
Size$^{\alpha}$	-0.065	0.085	0.008	-0.021	0.024	0.070
Building materials, rubber, and plastics$^{\alpha}$	-0.073	-0.041	-0.056	-0.035	-0.071	-0.017
Chemicals, textiles, and apparel$^{\alpha}$	-0.006	0.045	-0.042	-0.004	0.029	-0.001
Electronics and electrical$^{\alpha}$	0.108*	0.080	0.107*	0.106*	0.051	0.024
Food, beverage, and medical$^{\alpha}$	0.027	-0.072	-0.062	-0.059	-0.044	-0.038
Mean	5.507	4.978	5.360	5.526	5.125	4.918
Std. deviation	0.776	1.072	0.945	0.987	1.055	1.083

Note: Bold and italic numbers on the diagonal are the square root of AVE; $^{\alpha}$ represents Kendall's tau-b correlations; two-tailored significance; ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.

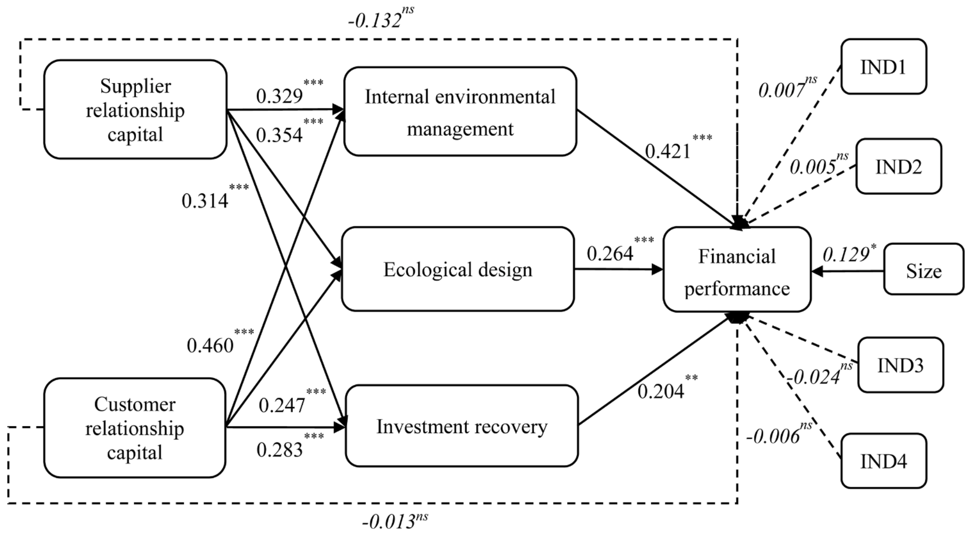

Fig. 3. SEM results.

*IND1: Building materials, rubber, and plastics; IND2: Chemicals, textiles, and apparel; IND3: Electronics and electrical; IND4: Food, beverage, and medical; ***p < 0.001; **p < 0.01; *p < 0.05;* ns: *p* > 0.05; *Bold line: significant, Dashed line: insignificant.*

through the "green process." The growing environmental awareness of the whole society will help promote product sales, increase market share, and enable profit growth for companies and even the entire supply chain. Therefore, it is not surprising that enterprise green management positively affects companies' financial performance, thus confirming the findings of extant studies, such as Chan et al. (2012), Schmidt et al. (2017), Sen et al. (2015) and Yu et al. (2020).

Second, three kinds of enterprise green management have differentiated impacts on a company's financial performance. Following Fig. 2, internal environmental management exerts the most significant influence on a company's financial performance, successively followed by ecological design and investment recovery. It is worth noting that investment recovery has the least impact on a company's financial performance. The implementation of investment recovery requires a large amount of upfront capital investment. The recovery period is more extended, which will affect a company's profits mostly, especially in the short term.

5.3. *Enterprise green management in mediating supply chain relationship capital affecting financial performance*

According to Fig. 2, there are no significant relationships between supply chain relationship capital and financial performance. However, the supply chain relationship capital positively affects enterprise green management. Moreover, enterprise green management also positively affects a company's financial performance. Therefore, we further conduct a bootstrapping mediation effect analysis to explore whether supply chain relationship capital indirectly affects a company's financial performance through enterprise green management using SPSS PROCESS (Hayes, 2013; Preacher and Hayes, 2008). The results are shown in Table 6. We find that supplier relationship capital indirectly affects a company's financial performance through three kinds of enterprise green management: 0.213, 0.122, and 0.088, respectively. The corresponding bias-corrected 95% confidence intervals are [0.111, 0.312], [0.017, 0.208], and [0.024, 0.164], respectively, thus indicating enterprise green management's role in mediating supplier relationship capital's impact on a company's financial performance. Meanwhile, the indirect effects of customer relationship capital on a company's financial performance through enterprise green management are 0.172, 0.075, and 0.061, respectively. The corresponding bias-corrected 95% confidence intervals are [0.072, 0.277], [0.003, 0.152], and [0.012, 0.128], respectively, thus indicating enterprise green management's role in mediating customer relationship capital's impact on a company's financial performance. In summary, enterprise green management mediates supply chain relationship capital's impact on firms' financial performance, thus enriching Yu et al. (2020) 's findings. The indirect effect through internal environmental management is the most significant, while the indirect effect through investment recovery is the least significant.

Table 6
Results of indirect effects test.

	Indirect effect	Bias-corrected 95% confidence interval		Significance
		Lower bound	Upper bound	
SuRC→InEM→FinP	0.213	0.111	0.312	Significant
SuRC→EcoD→FinP	0.122	0.017	0.208	Significant
SuRC→InvR→FinP	0.088	0.024	0.164	Significant
CuRC→InEM→FinP	0.172	0.072	0.277	Significant
CuRC→EcoD→FinP	0.075	0.003	0.152	Significant
CuRC→InvR→FinP	0.061	0.012	0.128	Significant

Note: SuRC = supplier relationship capital; CuRC = customer relationship capital; InEM = internal environmental management; EcoD = ecological design; InvR = investment recovery; FinP = financial performance.

5.4. *Managerial implications*

Industry 4.0 has brought profound changes to the manufacturing industry and promoted the intelligent transformation and upgrading of traditional manufacturing industries. Digitization of the manufacturing industry is an inevitable trend. In this context, various practices (e.g., construction of supply chain relationship capital and implementation of enterprise green management) will undoubtedly be affected by advanced information technologies, thus showing different efficiencies.

First of all, building supply chain relationship capital contributes to the implementation of enterprise green management. Manufacturing companies should strive to develop adequate supply chain relationship capital with the help of advanced information technologies to better implement green management in digital transformation under Industry 4.0. Specifically, companies should follow the principle of mutual benefit and respect to boost interactions with suppliers through regular information exchanges, employee training, and executive visits. As important technology systems, supplier relationship management systems, cloud procurement service platforms, or cloud procurement collaborative management systems can be utilized to encourage suppliers to actively participate in manufacturers' green practices and provide relevant inputs. This will help manufacturers improve product quality and product design, introduce new products or processes, and reduce inventory costs and the time it takes for products to reach the market.

Meanwhile, the social system is equally important. Based on respect, friendliness, and mutual trust, companies should strengthen their interactions with customers through telephone greetings or door-to-door visits. They should engage in conference training by focusing on collecting timely feedback from customers through customer relationship management systems and conducting data mining with big data to enhance customers' loyalty. This will help manufacturers increase environmental awareness, optimize product design, and improve manufacturing and recycling processes. Therefore, the coexistence of social supply chain relationships and Industry 4.0 technologies will maximize the efficacy of green management initiatives. In particular, for three types of enterprise green management and two kinds of supply chain relationship capital, manufacturing companies should focus on different practices according to their different needs. In terms of green management, if a manufacturer wants to better implement internal environmental management and investment recovery, it should pay more attention to establishing customer relationship capital. In contrast, if a manufacturer aspires to improve the ecological design, it should focus on building supplier relationship capital. Meanwhile, supplier relationship capital has the most potent effect in promoting ecological design, and it is essential to build supplier relationship capital for manufacturing companies committing to ecological design. Customer relationship capital has the most prominent role in promoting internal environmental management, and it is particularly urgent to build customer relationship capital for manufacturing companies implementing internal environmental management. Therefore, in terms of different green management practices, manufacturing companies should focus on additional relationship capital, thus leading to the best results. Meanwhile, building good relationship capital with suppliers and customers is also crucial for maintaining the stability and resilience of the industrial supply chain in digitizing the manufacturing industry under Industry 4.0, especially for dealing with emergencies. During the COVID-19 pandemic, as important nodes in the global supply chain, Chinese manufacturing companies quickly recovered with super resilience, injecting vitality into the global economy.

Secondly, enterprise green management can bring substantial financial benefits, confirming the necessity of implementing enterprise green management for manufacturing companies, especially in implementing digital manufacturing under Industry 4.0. The emergence of Industry 4.0 requires manufacturers to implement enterprise green management during the implementation of digital manufacturing. In the process of enterprise green practices, due to the investment of a large amount of capital, human resources, and material resources in the early stage, it is unlikely for the company to gain profits and sales performance immediately (Paulraj and Jong, 2011). However, in the long run, enterprise green management can improve companies' performance through effective environmental risk management and active continuous improvement (Gil et al., 2001). The successful implementation of enterprise green management involves effective coordination of environmental protection strategies with companies' goals and product positioning. Implementing proactive pollution prevention procedures through integrating Industry 4.0 practices with lean management can help companies reduce production costs, increase product value and market competitiveness, and enhance brand image. Enterprise green management will reduce waste disposal, pollutant emissions, and environmental incidents, thus increasing companies' economic benefits. Besides, enterprise green management can lead to ecological improvements and cost savings, reflecting the company's willingness and capability to supply environmental products and services for changing needs; this helps increase the market share of its products. Meanwhile, enterprise green management is also a kind of socially responsible behavior. Based on the stakeholder theory, fulfilling social responsibility will bring substantial financial benefits and maximize the overall interests of stakeholders (Brammer and Millington, 2008; McGuire et al., 1988). In summary, manufacturers should implement internal environmental management (total green management, cross-functional green cooperation, and ISO certification), carry out the ecological design (using life cycle assessment, modularization, and concurrent engineering), and implement investment recovery (through recycling and sale), to obtain the best financial returns in digital transformation under Industry 4.0.

Finally, establishing supply chain relationship capital can improve a company's financial performance by promoting enterprise green management practices in implementing digital manufacturing promoted by Industry 4.0. To obtain better economic benefits, manufacturers should pay attention to developing good partnerships with supply chain upstream and downstream partners and regard them as essential resources to facilitate enterprise green management with the help of Industry 4.0-based information technologies. Cooperating with suppliers can ensure green input from the source, and interacting with customers can obtain honest feedback on green demands, both of which are necessary prerequisites for manufacturers to implement enterprise green management. In terms of three kinds of enterprise green management practices, manufacturers should first focus on internal environmental management, which is currently the most common green or ecological practice. Second, carrying out green design in collaboration with upstream and downstream partners has become one of the mainstream trends of industrial design today, as environmental-friendly products become more popular to yield significant financial gains for companies. Finally, as an important part of the closed-loop supply chain, inviting suppliers and customers to construct and better recycle recycling systems contributes to environment protection, cost reduction, and improved financial outcomes. Therefore, with the help of Industry-4.0-based information technologies, manufacturers undergoing digital transformation are more likely to gain financial benefits from implementing green management initiatives.

6. Conclusions

Based on the social-technical system theory, social capital theory, and resource-based theory, this paper explores the impacts of supply chain relationship capital and enterprise green management on manufacturing companies' financial performance during their digital transformation in the context of Industry 4.0. With the data collected from 308 Chinese manufacturing companies undergoing digital transformation in Industry 4.0, we conduct analysis based on structural equation modeling and SPSS PROCESS. The findings show that supply chain relationship capital positively affects enterprise green management and enterprise green management enhances financial performance, while enterprise green management mediating supply chain relationship capital's indirectly effect on financial performance. The results contribute to the literature on relationship capital and green management by extending the connotation of relationship capital in the supply chain and enriching the practical form of green management. Our research provides practical guidance for companies undergoing digital transformation in Industry 4.0 to exploit supply chain relationship capital to enhance their financial performance through implementing green management initiatives.

However, this study still has several shortcomings. First, we only used cross-sectional data for hypothesis testing and model verification. Future research can use longitudinal data and public data such as corporate annual reports to enhance the reliability of our findings. Second, the sample companies are all from the manufacturing industry in Zhejiang Province, China. Future studies can be expanded to other areas in China or other countries as well as other industries to improve the external validity of our findings. Third, this study only discusses the direct and indirect effects, which are likely to be affected by other factors. The impact of moderating variables, such as institutional environment, competitive intensity, and environmental turbulence, should also be analyzed in future studies to enrich the theoretical framework. Finally, Industry 4.0 has triggered some significant changes in the operations of enterprises and supply chains. Future research should examine how these changes will affect the development of relevant enterprise green practices, such as the level of informatization, institutional mechanisms, environmental regulations, and relationship characteristics.

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Appendix A. Measures

Supply chain relationship capital (Adapted from Carey et al. (2011) and Villena et al. (2011))

To what extent do the following statements describe your company's relationship with key suppliers/customers? [1–7: *not at all–a very great extent*]

Supplier—customer relationship capital

SuRC1/CuRC1: Keep close interaction at multiple levels
SuRC2/CuRC2: Keep mutual trust at multiple levels
SuRC3/CuRC3: Keep mutual respect at multiple levels
SuRC4/CuRC4: Keep mutual friendship at multiple levels
SuRC5/CuRC5: Keep high levels of reciprocity

Enterprise green management (Adapted from Zhu and Sarkis (2004), Sarkis et al. (2010) and Zhu et al. (2013))

Please indicate the extent to which you agree or disagree with each of these statements about your company. [1–7: *strongly disagree–strongly agree*]

Internal environmental management

InEM1: Commitment of green management from senior managers
InEM2: Support for green management from mid-level managers
InEM3: Cross-functional cooperation for environmental improvements
InEM4: ISO 14001 certificate
InEM5: Total quality environmental management
InEM6: Environmental compliance and auditing programs
InEM7: Environmental management systems exist

Ecological design

EcoD1: Design of products for reduced consumption of material or energy
EcoD2: Design of products for reuse, recycle, recovery of material, components, parts
EcoD3: Design of products to avoid or reduce the use of hazardous products or their manufacturing process
EcoD4: Use of LCA for product design
EcoD5: Use of easy-to-break joints between components to facilitate disassembly
EcoD6: Use of standardized components to facilitate their reuse
EcoD7: Design of processes for minimization of waste

Investment recovery

InvR1: Investment recovery (sale) of excess inventories or materials
InvR2: Sale of scrap and used materials
InvR3: Sale of excess capital equipment
InvR4: Collecting and recycling end-of-life products and materials
InvR5: Establishing a recycling system for used and defective products

Financial performance (Adapted from Flynn et al. (2010) and Huo (2012))

Please evaluate your company's performance in the following areas relative to your primary/major competitors. [1–7: *much worse–much better*]

FinP1: Growth in sales
FinP2: Growth in profit
FinP3: Growth in market share
FinP4: Growth in return on investment
FinP5: Growth in return on sales

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