Journal of Global Information Management
Volume 32 • Issue 1 • January-December 2024

State Ownership and Green Innovation:
The Moderating Role of Digitalization

Renhao Liu
Sun Yat-sen University, China

Beifan Zhang
University of Technology, Sydney, Australia

Tong He
Xi'an Jiaotong-Liverpool University, China

Youqing Fan
https://orcid.org/0000-0001-9508-5411
Western Sydney University, Australia

Shuang Li
University of Warwick, China

ABSTRACT

Climate change and digital transformation have significant effects on all aspects of society. With the increasing importance of state-owned enterprises (SOEs) that represent governments' stand to respond to environmental challenges, this study investigates how state ownership affects green innovation and how digital transformation factors play a role at both the firm level and the provincial level. Based on the data analysis of Chinese listed firms between 2008 and 2021, we find that state ownership hinders green innovation. However, with a high degree of digital transformation at the firm level and digital innovation capability at the province level, the state ownership and green innovation relationship can be weakened. Overall, this study advances both green innovation and SOE innovation literature by bridging state ownership, green innovation, and digital-related factors. We advocate government and SOE managers to invest more in digital transformation and improve their digital capabilities for better green innovation output.

KEYWORDS

Digital Transformation, Digitalization, Green Innovation, State Ownership

INTRODUCTION

Climate change and sustainability have gained increasing attention from practitioners and scholars. In response to the worldwide concern for environmental issues, green innovation, which is regarded as one of the important means for reducing environmental pollution, increasing energy and resource utilization efficiency, improving overall operational productivity, and enhancing firm legitimacy, is widely adopted by many firms (Chen, 2008; Liu et al., 2021; Matos et al., 2022). Governments also play an important role in promoting a firm's green innovation (Horbach, 2008; Kassinis & Vafeas, 2006; Wang et al., 2018). On the one hand, the government sets strict standards by formulating environmental regulations and supervising firms' environmental activities (Berrone et al., 2013; Wang et al., 2018; Xu et al., 2022). On the other hand, it provides firms with R&D funds, subsidies,

DOI: 10.4018/JGIM.347502

and green policies to respond to market failure and externalities related to green innovation (Chen, 2008; Guo et al., 2016; Jaffe et al., 2005).

Furthermore, governments are also actively involved in green innovation with their influence on state-owned enterprises (SOEs). Compared to private-owned enterprises (POEs) whose main goal is for profit maximization, SOEs are more politically-connected and are subjected to greater governments pressure (Zhou et al., 2017). However, increasing attention has been paid to the relationship between state ownership and firms' green innovation, but with mixed findings (Wang & Jiang, 2021). According to the logic of institutional view, some studies argue that state ownership promotes green innovation through easier acquisition of more resources, such as land, financial capital, favorable policies, and greater legitimacy (Bai et al., 2019; Chen et al., 2014; Li & Zhang, 2007; Wang & Jiang, 2021). As delegates of governments, SOEs have greater expectations from the government than non-SOEs to take the initiative and play an exemplary role in developing green innovation (Li & Lu, 2016; Wang & Jiang, 2021). On the other hand, according to the logic of efficiency, state ownership hinders firms' green innovation as state-owned enterprises lack incentives to pursue market-driven, efficiency-based goals (Ramamurti, 2000). This argument is more dominant in the reviewed literature, especially in the context of emerging markets where legal systems and market institutions are underdeveloped, and governments' interventions are highly intense (Choi et al., 2011; Jiang et al., 2020). Managers in state-owned enterprises (SOEs) have insufficient willingness and capacities needed for green innovation (Li & Lu, 2016). As green innovation is often risky, uncertain, and long-term based, SOE managers tend to secure their political careers in the short term (Bai et al., 2019; Li & Lu, 2016; Tan, 2002). As their careers are often promoted by their political linkages rather than their business mindset and functional expertise, their capacities required by green innovation are also limited (Li & Lu, 2016; Tan, 2002). Such inconsistency remains to be addressed and deserves more exploration.

In this study, we first develop our baseline relationship between SOEs and green innovation. Then, we focus on the role of digital transformation to reconcile the mixed findings in the existing literature. Digital transformation (DT) is defined as an evolutionary process through the use of new digital technologies to enable major business improvements and to create values to customers (Gong & Ribiere, 2021). Notably, recent developments in digital technologies such as artificial intelligence, big data, cloud computing, and the Internet of Things (IoT) are increasingly influencing all aspects of the economy and society. Recent studies suggest that firms' digital transformation can promote their economic, social and environmental performance (Fang et al., 2023; Meng et al., 2022). As firms can access and process massive real-time information and make timely adjustments, the use of advanced digital technology can effectively help reduce production costs and improve processes such as product design, production, management, and marketing, thus increasing productivity and financial performance (Li et al., 2023b). On the other hand, digital technologies also help to enhance human resource management efficiency and green innovation capacity to make a positive social and environmental impact (Cardinali & De Giovanni, 2022; Du et al., 2023; Lu et al., 2023; Meng et al., 2022; Wen et al., 2022). However, very limited studies have considered how digital-related factors such as provincial digitalization environment and the use of digital technologies influence SOEs' green innovation. Wang and Jiang (2021) explored the role of environmental factors, including legal development and industry uncertainty, and firm factors such as a board chair's functional expertise and firm resources in SOEs' green innovation. Additionally work by Feng et al. (2022) revealed the positive effect of digital transformation on SOEs' green innovation. Due to the increasing importance of digitalization and its role in improving firms' operations and financial flexibility (Tian et al., 2022), it is imperative to introduce digital factors into our discussion. On the one hand, we suppose that firm's digital transformation can help improve SOEs' operational and organizational efficiency. This leads to the optimization of green R&D resource allocation. Also, it promotes managers in SOEs by improving information symmetry and their business expertise, thus enhancing their willingness needed for green innovation. On the other hand, the moderating factor, province-level digital innovation capacity, creates a favorable environment for firms' green innovation by improving firms' access to

more resources and increasing SOE managers' willingness for green innovation, as digital know-how spillovers are faster and stronger within the province.

Overall, this study aims to resolve the inconsistency in the relationship between state ownership and green innovation. Based on empirical analysis from Chinese firms, we argue that firms with a higher level of state ownership tend to engage less in green innovation as they are reluctant to take risks and lack innovation capacities. Then, we introduce digital transformation as moderators to explore to what extent SOE improves or hinders green innovation. Notably, we focus on two levels of digital factors: the firm's level of digital transformation and the province's level of digital innovation capacity. Given the benefits associated with a firm's digital transformation and digital innovation capacity at the province level, we argue that the negative relationship between state ownership and green innovation can be weakened when provincial and firm levels of digital transformation are high.

Using a sample of Chinese firms between 2008 and 2021, our study makes two main contributions to the existing literature. First, we contribute to green innovation literature by resolving the negative impact of state ownership on green innovation by introducing digital-related factors to the relationship. The significant role of a firm's digital transformation and digital innovation capacity at the province level underscores the importance of digital factors in influencing how much SOEs contribute to green innovation, which is underestimated in previous studies. Second, we also advance SOE innovation literature on building a linkage between SOEs' innovation and digitalization. Although there are a number of studies focusing on exploring how much SOEs can improve innovation (Cao et al., 2020; Tihanyi et al., 2019; Zhou et al., 2017), the role of digitalization is still largely understudied. Our study sheds light on the value of investigating digital factors in SOE innovation studies.

THEORETICAL DEVELOPMENT AND HYPOTHESIS DEVELOPMENT

Green Innovation

Green innovation refers to new or modified processes, techniques, systems, and products intended to prevent or reduce negative environmental impacts (Kemp et al., 2001; Rennings, 2000; Schiederig et al., 2012). It is often interchangeably used with three other notions: sustainable innovation, environmental innovation, and ecological innovation (Dangelico & Pujari, 2010; Rennings, 2000; Schiederig et al., 2012).

Firms are motivated to engage in green innovation due to business and social incentives. First, green innovation can help improve firms' financial benefits and improve firms' business competitiveness (Chen et al., 2006; Cheng et al., 2014; Lee & Min, 2015; Xie et al., 2019). Specifically, it helps save resources, reduce production and operation costs, improve energy efficiency, and develop new market opportunities, thus achieving better business performance (Chen et al., 2006; Dangelico & Pujari, 2010). Second, green innovation creates social value for firms. Under the rise of consumer environmental consciousness (Peattie, 2008), green innovation helps firms build a green image and reputation for outsiders. This enhances firms' environmental legitimacy. Third, firms can gain more policy and financial support from governments who are under pressure to go green through green subsidies, green loans, and green R&D investments (Guo et al., 2016; Huang et al., 2019; Xia et al., 2022). Therefore, all the above benefits promote firms' engagement in green innovation.

However, in spite of various advantages, green innovation concerns discourage firms from investing in green innovation. First, green innovation is inherently costly, uncertain, risky, and long-term based (Chrisman & Patel, 2012 & Ma et al., 2019). Additionally, in contrast with other innovations, green innovation suffers from double-externality problems: 1) innovating firms are unable to prevent other firms or society from enjoying the innovation while the costs are covered by the innovator alone (Liu et al., 2024) and 2) green innovation is able to mitigate negative externalities stemming from environmental pollutions but such environmental pollutions are hard to be quantified, creating a situation where firms generally lack the incentive to minimize their environmental impact to a socially desirable level (Rennings, 2000; Xia et al., 2022).

Due to the abovementioned complexity of green innovation, most literature has focused on firm-level factors to explore how and to what extent firms will conduct green innovation. Based on the resource-based view (RBV) (Barney, 1991), it is suggested that firms with sufficient resources and innovative capacities will be more likely to adopt green innovation (Ardito et al., 2019; Cheng, 2020; Horbach, 2008; Jefferson et al., 2003; Wagner, 2007). For instance, Lee and Min (2015) demonstrate that firms with green R&D investments can develop unique resources and capacities that result in better performance.

Emerging literature focuses on how different firms' ownership (e.g., private ownership, state ownership, institutions) in impacting green innovation, especially the role of state ownership (Chen et al., 2014; Jefferson et al., 2003; Qu & Pan, 2023; Tan, 2002). However, the relationship between SOEs and green innovation has not yet reached a consensus. One group of scholars finds that firms with high levels of state ownership are more likely to conduct green innovation because of their resource access advantages and more environmental responsibilities (Chen et al., 2014; Zhou et al., 2017). In contrast, other literature suggests that managers in firms with state ownership are often risk-averse and reluctant to engage in green innovation (Tan, 2002; Tihanyi et al., 2019). Also, state owned firms have insufficient capacities needed for green innovation (Liu et al., 2020).

Given the inconsistent findings in the literature, exploring the contingencies under which state ownership can increase or decrease green innovation is essential. In the era of rapid development of digitization, we cannot ignore the power of digital factors in supporting SOEs' green innovation (Karimi Takalo et al., 2021). To address the aforementioned research void, our study builds on prior green innovation research and tries to resolve these theoretical and empirical inconsistencies by exploring the moderating role of digital-related factors in the relationship between state ownership and green innovation.

State Ownership and Green Innovation

States have become dominant owners of companies in many countries around the world, especially in emerging markets like China (Li & Lu, 2020; Marquis & Qian, 2014; Wang et al., 2018). State ownership refers to the percentage of stake the government controls in a firm (Commission, 2016; Zhou et al., 2017). State-owned enterprises (SOEs) are firms with government ownership and are operated and managed by the state. Compared to non-SOEs or private-owned enterprises (POEs), SOEs represent the government's interest and carry out activities subject to the government's policies, regulations, and environmental and social responsibilities (Lazzarini et al., 2021; Liu et al., 2021). As such, state ownership significantly affects a firm's strategic choices (Cui et al., 2022; Tan, 2002; Tihanyi et al., 2019), particularly green innovation.

Previous studies present conflicting findings on the relationship between state ownership and green innovation. On the one hand, some scholars suggest that state ownership promotes green innovation. According to the institutional view, SOEs are naturally politically connected and have better access to government resources than non-SOEs (Wang & Jiang, 2021; Zhang et al., 2022). These resources include land, technical infrastructure, green subsidies, bank loans, R&D grants, low-cost capital and the latest policy information for green development (Chen et al., 2014; Pan et al., 2020; Peng & Luo, 2000; Zhou et al., 2017). Green innovation often requires substantial investments (Bansal & Roth, 2000; Berrone et al., 2013). With such government support, SOEs enjoy privileges granted by governments that alleviate constraints of resources that are essential for green innovation (Wang & Jiang, 2021; Zhou et al., 2017). Furthermore, having government as owner, SOEs hold more environmental responsibilities than non-SOEs, which makes them more responsive to governments' call for the progress of green development (Pan et al., 2020; Qu & Pan, 2023; Wang et al., 2018; Zhou et al., 2017).

On the other side, however, we argue that the negative impact of state ownership on green innovation is more dominant than the positive impact. There are two reasons explained below that support this argument. First, managers in SOEs lack the willingness to engage in green innovation.

Unlike non-SOE firms, SOE managers are often appointed directly by governments and are defined as public employees (Zhou et al., 2017). Managers cannot only consider profits, but must also bear the burden of R&D investments for the government's green agenda (i.e., green innovation) due to their role as government delegates (Bai et al., 2019). Thus, they are often reluctant to innovate due to fewer incentives and the unavoidable financial burdens from governments' requests. Additionally, managers in SOEs often care more about their political careers in the short term and pay little attention to the firm's long-term performance, which is led by innovation (Bai et al., 2019; Li & Lu, 2016; Liu et al., 2020). As job maintenance is the key goal for SOE managers, they are often risk-averse and reluctant to innovate (Tan, 2002; Tihanyi et al., 2019). Therefore, they have weak internal incentives to make risky innovation decisions.

Second, SOEs have insufficient capabilities for green innovation. SOEs are owned not by an entity but by society and the whole population. Firms with state ownership belong to the public, and managers are free of constraints (Ramamurti, 2000). This freedom allows managers to use firms' resources for their own interests instead of prioritizing firms' performance. This may distract resource allocations for developing firms' green innovation capacity. As a result, the efficiency of resource allocation and utilization is compromised. Also, as mentioned above, managers may lack the willingness to engage in market-driven and efficiency-based activities, gradually losing competitiveness and innovativeness over time (Zhou et al., 2017). Additionally, SOE managers are often selected based on political knowledge rather than business expertise (Tan, 2002; Zhou et al., 2017). They normally lack a market mindset for daily operations, which is important to develop efficient green innovation. Empirical studies also echo this conclusion that POEs have more innovation capacities than SOEs (Liu et al., 2020).

Taken together, although there are benefits associated with SOEs, the low level of willingness and capacity to conduct green innovation overtakes benefits. Therefore, we hypothesized our baseline hypothesis:

Hypothesis 1: Firms with a high (low) level of state ownership tend to engage less (more) in green innovation.

The Moderating Effect of Firms' Level of Digital Transformation

Given the negative impact of state ownership on green innovation, we further propose that such a negative impact will be mitigated when the firm has a high degree of digital transformation for the following reasons.

First, digital transformation enhances SOEs' green innovation capabilities. Green innovation capabilities normally refer to product and process innovation capacities in pollution prevention, green product designs, energy-saving, and waste recycling (Chen et al., 2006). Using digital technologies, firms' overall operational and organizational efficiency is improved (Alojail & Khan, 2023; Liu et al., 2023; Xue et al., 2022). For example, Alojail and Khan (2023) found that digital transformation can provide organizations with high productivity tools to reduce inefficient and work tasks, leading to higher accuracy and, consequently, better operational efficiency. Chen et al., (2020) found digitalization can help build more sustainable manufacturing by tracking and optimizing resource use and more effective communication over the whole life cycle among employees and customers. This efficiency leads to the optimization of green R&D resources, and better SOE financial and environmental performance, thus helping build more robust green innovation capacities.

Second, digital transformation promotes SOE managers by improving information symmetry and risk-taking courage needed for green innovation. Liu et al. (2023) found that every 1% increase in financial digital transformation leads to 15.1% growth in the information symmetry level. With the use of digital technologies, firms can capture and update market information quickly, accurately, and systematically, making real-time adjustments accordingly (Alojail & Khan, 2023; Chen, 2020; Du et

al., 2023; Li et al., 2020; Xue et al., 2022). It increases managerial risk-taking by improving operational flexibility and financial availability (Tian et al., 2022). Because of information transparency, it is proved that digital transformation can also change the organizational culture from a high level of uncertainty avoidance towards a lower level of the dimension (Pfaff et al., 2023). In this way, SOE managers are promoted to make innovative decisions that usually involve risks with more comprehensive and real-time information and a feeling of certainty. As mentioned above, SOE managers are usually appointed based on their political background rather than their functional business expertise. The decrease of information asymmetry by digital transformation enhances the ability of SOE managers to cope with changes in external environments and compensates them with the required knowledge and capacities of SOE managers for better green innovation output.

Furthermore, SOEs with a high level of digital transformation endow a culture of innovation. Green innovation often involves knowledge spillover (Aldieri et al., 2019). The use of digital technologies enhances processes for better information sharing and communications within firms, thus improving the quality and quantity of knowledge sharing. This is due to the high level of autonomy and flexibility that the digital workplace provides to employees, and it also helps to foster good collaborative relationships between managers and subordinates, which are beneficial for innovation activities (Baumgartner et al., 2021). Digital transformation does not mean only the adoption of digital technologies. It also implies changes to firms' organizational culture (Baumgartner et al., 2021; Pfaff et al., 2023). Martins and Terblanche (2003) viewed organizational culture as an organization's shared deep-seated ideas and values. Digital transformation changes the company's organizational culture towards increased collectivism, long-term orientation, and less uncertainty avoidance, which are vital for promoting a culture of innovation (Pfaff et al., 2023). Therefore, SOEs with a high level of digital transformation are more likely to enjoy using digital technologies for green innovation activities and are more willing to share innovation ideas that are impossible without digital transformation.

Taken together, we thus propose the following:

Hypothesis 2: The negative relationship between state ownership and green innovation is weakened when firms have a high level of digital transformation.

The Moderating Effect of Digital Innovation Capacity in Province

The impact of the macro-environment, such as the digital innovation environment, on business innovation has received increasing attention (Caballero et al., 2022; Huang et al., 2022). We expect that the negative impact of state ownership on green innovation will also be weakened when firms operate in provinces with high levels of digital innovation capacity.

First, firms with state ownership are likely to receive more resources in provinces with high digital innovation capacity. Using Chinese provinces as an example, researchers found that the development of the digital economy varies significantly from province to province (Huang et al., 2022; Xu & Li, 2022). In China particularly, because of significant differences in economic development, urbanization, and population density, eastern provinces such as Guangdong and Zhejiang enjoy more advanced digital development than rural provinces (Liu et al., 2022). Provincial governments in China also play an essential role in driving digital transformation through policies, investment strategies, and incentives. In general, when the province has a high level of digital innovation capacity, the provincial government prioritizes digital technologies and is willing to support the development of digital innovations through more favorable subsidies, R&D expenses, and digital infrastructure constructions (Kuo et al., 2019). Firms with state ownership can take advantage of greater access to the government's abundant digital advance provisions such as high-speed internet connectivity, mobile networks, better digital payment systems, a workforce with better digital skills, and digital development subsidies, thus improving their overall digital capacities for decision-making.

Second, when firms operate in provinces with high levels of digital innovation capacity, firms with state ownership will be more willing to engage in green innovation because of the benefits of digital innovation spillovers within the same province. A favorable digital business environment generally accompanies an inflow of digital talent, technologies, and other resources (Li & Lu, 2023). The province with high digital innovation capacity is characterized by stronger innovation systems with more research institutions, universities, and start-up incubators (Tian et al., 2023). Firms in provinces with robust digital innovation capacity will experience faster digital know-how spillovers (Liu et al., 2023; Zhao et al., 2015; Xu et al., 2024). As firms with state ownership usually are less motivated to pursue green innovation due to high risks, a provincial environment with faster digital spillovers will equip managers lacking business expertise with more real-time data for making decisions and adjustments accordingly. Therefore, firms with state ownership are motivated to take more risky decisions associated with green innovation. Overall, the spillover effects associated with a high level of digital innovation capability not only improve firms with state ownership access to digital-related resources, but also improve their willingness to engage in the use of digital technologies. As a result, a firm's efficiency in conducting green innovation increases.

Taken together, we argue that firms with state ownership operating in a province with a high level of digital innovation capacity are likely to increase their capacity and willingness to conduct green innovation via leveraging benefits from digital resources within the province, thus mitigating the negative impact of state ownership on green innovation. Thus, we propose:

Hypothesis 3: The negative relationship between state ownership and green innovation is weakened when the firm operates in provinces with a high level of digital innovation capacity.

METHODOLOGY

Database

The study adopted a sample of Chinese firms listed on the A-share markets of the Shanghai and Shenzhen Stock Exchanges from 2008 to 2021. We used the Chinese Research Data Services (CNRDS) database to collect firm-level financial data and information on firms' green patents. The CNRDS is a widely adopted database used in previous Chinese research (Gu at al., 2022; Yao at al., 2023). Province-level data was sourced from various years of the *China Province Statistical Yearbook*, published by the National Bureau of Statistics of China (Liu et al, 2021).

Measurement

Green patent. Following prior studies (Ren et al., 2022), green innovation was measured as the total count of green patents applied in a certain year. Every patent has a unique IPC classification. Whether the patent is green can be determined if the IPC falls into the list of the IPC Green Inventory, a widely used international classification (Orsatti et al., 2020; Ren et al., 2022).

State ownership. We followed previous studies and measured state ownership, the ratio of firm shares owned by the state to a firm's total shares (Jia et al., 2019; Pan et al., 2020; Zhou et al., 2017).

Firms' digital transformation. To capture the degree of Chinese firms' digital transformation, we followed previous studies (Chen et al., 2023; Zeng et al., 2022) and adopted a textual mining approach to extract keywords related to digital transformation. We first followed prior studies (Chen et al., 2023; Lu et al., 2023; Zeng et al., 2022) and identified all the keywords related to artificial intelligence, cloud computing technology, blockchain, big data, and application of digital technologies. Then, for each firm, we measured firms' digital transformation as the total number of digital transformation-related key words mentioned in each year's annual report.

To be accurate, we only focused on the focal firm's digital transformation and eliminated any expressions from the annual report from shareholders, customers, and suppliers.

Province digital innovation capacity. We calculated the total number of digital patents applied in a certain province to capture the digital innovation capacity at the province level. We sourced patent data from China National Intellectual Property Administration and followed an official document by the China National Bureau of Statistics on the digital economies to identify whether the patent is a digital patent (Liu et al., 2021; Wang et al., 2023).

Control variables. Sets of variables were also included as controls that could affect green innovation. At the firm level, we controlled for firm age, calculated as the logarithm of the total number of years since the firm's inception (Berrone et al., 2013). We also controlled for firm size, measured as the logarithm form of a firm's total assets (Berrone et al., 2013; Yang et al., 2023). As resources facilitate resource-consuming green innovation, we controlled for financial slack, which measured the total current assets to total current liabilities ratio (Chrisman & Patel, 2012; Kim et al., 2008). In addition, as R&D investments are critical for innovation, we also controlled for R&D intensity as the total amount of expenses on research and development divided by total sales (Li et al., 2021). At the industry level, we controlled for industry concentration by calculating the Herfindahl index at a two-digit industry level. At the province level, we controlled GDP per capita to capture economic development in the province. We also winsorized all continuous variables at 99% to mitigate outlier influences.

Estimation Method

As our dependent variable is the count variable, we employed the Poisson random effect panel regression to test our hypothesis. Compared to the negative binomial model, the Poisson estimator relies on weaker distributional assumptions and produces more consistent and robust estimates of the parameters even if the variances are misspecified (Cameron & Trivedi, 2009; Jia et al., 2019; Wooldridge, 1999). Thus, the following is our estimation model.

$$\begin{aligned} Green\ innovation_{it} &= \beta_0 + \beta_1 State\ ownership_{it-1} + \beta_2 State\ ownership_{it-1} \\ &* Firm's\ digital\ transformation_{it-1} + \beta_3 State\ ownership_{it-1} \\ &* Province\ digital\ innovation\ capacity_{it-1} + \beta Controls_{it-1} + \varepsilon_{it-1} \end{aligned}$$

where *i* indicates firms, *t* indicates year, *Controls* is a vector of control variables, and ε_{it-1} is the error term. All the independent variables and control variables were lagged by one year to mitigate concerns about endogeneity. We also included time- and industry-fixed effects in all estimations to control for unobserved heterogeneities associated with time and industry. To test Hypothesis 1, we are interested in β_1 and for Hypotheses 2 and 3, β_2 and β_3 are of interest.

RESULTS

Table 1 shows the means, standard deviations, and correlations describing the variables. All significant correlations are below 0.4. The largest variance inflation factor is 1.95, substantially below the rule-of-thumb cutoff of 5 (Ryan, 1997). Therefore, multicollinearity is not a major concern for our study.

Table 2 reports the estimation results of the relationship between state ownership and green innovation. Model 1 is the baseline model, which only includes the control variable. Model 2 adds *State ownership* to test Hypothesis 1. Model 3 adds the interaction term on *State ownership * Firm's digital transformation* to test Hypothesis 2. Model 4 adds the moderation effect of *Province digital innovation capacity* to test Hypothesis 3. Model 5 is the full model.

Table 1. Descriptive analysis and correlation matrix

Variables	*Mean*	*SD*	1	2	3	4	5	6	7	8	9	10
1. Green innovation	1.94	5.28	1									
2. State ownership	0.03	0.1	0.02	1								
3. Firm digitalization	2.09	1.13	0.06	-0.05	1							
4. Province digital innovation capacity	10.52	1.31	0.05	-0.09	0.18	1						
5. Firm age	2.91	0.31	-0.02	-0.02	0.03	0.14	1					
6. Firm size	22.11	1.28	0.27	0.16	-0.01	-0.01	0.23	1				
7. Financial slack	2.73	2.68	-0.09	-0.05	0.05	0.01	-0.22	-0.38	1			
8. R&D intensity	0.05	0.05	0.04	-0.07	0.31	0.13	-0.13	-0.28	0.36	1		
9. Industry concentration	0.79	0.25	0.05	-0.04	-0.08	0.03	-0.14	-0.14	0.14	0.06	1	
10. Province GDP per capita	11.24	0.43	0.01	-0.07	0.19	0.69	0.14	0.05	0.01	0.15	-0.03	1

Note: N = 13,712. Correlation coefficients with values lower than |0.0169| are significant at 5% level

Hypothesis 1 proposes that firms with higher state ownership tend to decrease their green innovation. In Model 2, the coefficient on *State ownership* (β = -0.3452 with $p < 0.01$) is significant and negative, supporting H1. This means that although firms with state ownership can have resource and legitimacy advantages, their negative impact still dominates.

In Hypothesis 2, we contend that the negative relationship between state ownership and green innovation is weakened when the firm has a high degree of digital transformation. In Model 3 of Table 2, the significant and positive coefficient on the interaction term *State ownership * Firm's digital transformation* (β = 0.2638 with $p < 0.01$) supports Hypothesis 2. Similarly, in Model 4, the interaction term on *State ownership*Province digital innovation capacity* (β = 0.3302 with $p <$ 0.01) is significant and positive, showing a weakened relationship between state ownership and green innovation. Overall, the results support our Hypothesis 3 that the negative relationship between state ownership and green innovation becomes weaker when firms operate in the province with strong digital innovation capacity.

Robustness Test

We also employed a few additional tests to check the robustness of our analysis. First, we adopted an alternative dependent variable. We use the total number of green patents that firms themselves apply rather than jointly to capture whether the firm is strong in green innovation. The results are shown in Table 3. In Model 1, the coefficient on *State ownership* (β = -0.3558 with $p <0.01$) is still significant, supporting Hypothesis 1. Similarly, in Model 2 and Model 3, the interaction coefficients on *State ownership * Firm's digital transformation* (β = 0.2697 with $p < 0.01$) and *State ownership*Province digital innovation capacity* (β = 3428 with $p < 0.01$) are all significant and positive, lending support to supporting Hypothesis 2 and Hypothesis 3.

Second, as state-owned firms might be different from non-state-owned firms, unobserved heterogeneities confound our proposed relationships. We adopted a propensity score matching (PSM) method to address this issue. We adopted all the variables from Table 1 in the PSM procedure. We first matched state-owned firms with non-state-owned firms, using STATA 18 command *psmatch2*. After matching, the median bias on all variables between state-owned groups and non-state-owned groups drops from 6.5 to 1.1, and the p-value for Chi-square drops to 0.99, suggesting a good match. We rerun our analysis in Table 2 using the matched samples. The results of Models 4-6 in Table 3

Table 2. Main results

	Model 1	Model 2	Model 3	Model 4	Model 5
Firm age	-0.0468	-0.0724	-0.0987	-0.0863	-0.0990
	(0.101)	(0.101)	(0.102)	(0.102)	(0.102)
Firm size	0.3604***	0.3667***	0.3723***	0.3705***	0.3731***
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
Financial slack	-0.0141**	-0.0142**	-0.0153**	-0.0151**	-0.0156**
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
R&D intensity	2.4273***	2.4422***	2.4306***	2.4633***	2.4527***
	(0.360)	(0.360)	(0.359)	(0.359)	(0.359)
Industry concentration	0.4459***	0.4430***	0.4425***	0.4397***	0.4399***
	(0.061)	(0.061)	(0.061)	(0.061)	(0.061)
Province GDP per capita	0.1693**	0.1535*	0.1452*	0.1517*	0.1473*
	(0.086)	(0.086)	(0.086)	(0.086)	(0.086)
Firm's digital transformation	0.0769***	0.0777***	0.0720***	0.0812***	0.0774***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Province digital innovation capacity	0.2086***	0.2119***	0.2120***	0.1896***	0.1927***
	(0.031)	(0.031)	(0.031)	(0.032)	(0.032)
State ownership		-0.3452***	-0.8318***	-3.6552***	-3.4928***
		(0.095)	(0.173)	(0.699)	(0.705)
State ownership * Firm's digital transformation			0.2638***		0.1536*
			(0.078)		(0.083)
State ownership * Province digital innovation capacity				0.3302***	0.2858***
				(0.069)	(0.073)
Constant	-12.4036***	-12.2342***	-12.1966***	-11.9439***	-11.9651***
	(1.003)	(1.005)	(1.005)	(1.007)	(1.007)
Observations	13712	13712	13712	13712	13712
Number of firms	3179	3179	3179	3179	3179
Log likelihood	-18777.34	-18770.40	-18764.64	-18758.41	-18756.71
Chi-square	1909.314	1920.534	1930.430	1939.195	1942.101
Prob > Chi-square	0.000	0.000	0.000	0.000	0.000

Note: ***p < 0.01, **p < 0.05, *p < 0.1; robust standard errors are in parentheses. All models included industry and year dummies.

show that our main results were all well aligned with those in Table 2. Therefore, endogeneity is not a major concern for our study and our results are robust.

DISCUSSION AND IMPLICATIONS

The relationship between green innovation and state ownership has attracted a great deal of attention, as state ownership plays a crucial role in driving the country's green development. In this

Table 3. Robustness check results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Alternative DV: self-applied green innovation			Regression after PSM		
Firm age	-0.3315***	-0.3539***	-0.3556***	-0.0694	-0.0914	-0.0813
	(0.112)	(0.113)	(0.113)	(0.101)	(0.102)	(0.102)
Firm size	0.3329***	0.3384***	0.3374***	0.3699***	0.3741***	0.3711***
	(0.021)	(0.021)	(0.021)	(0.019)	(0.019)	(0.019)
Financial slack	-0.0157**	-0.0169**	-0.0165**	-0.0140**	-0.0149**	-0.0146**
	(0.007)	(0.007)	(0.007)	(0.006)	(0.006)	(0.006)
R&D intensity	2.2685***	2.2638***	2.2868***	2.4846***	2.4704***	2.4824***
	(0.392)	(0.392)	(0.392)	(0.360)	(0.360)	(0.359)
Industry concentration	0.3824***	0.3827***	0.3787***	0.4448***	0.4440***	0.4410***
	(0.070)	(0.070)	(0.070)	(0.061)	(0.061)	(0.061)
Province GDP per capita	-0.1280	-0.1367	-0.1340	0.1421*	0.1360	0.1436*
	(0.096)	(0.096)	(0.096)	(0.086)	(0.086)	(0.086)
Firm's digital transformation	0.0936***	0.0881***	0.0971***	0.0818***	0.0767***	0.0826***
	(0.014)	(0.014)	(0.014)	(0.012)	(0.012)	(0.012)
Province digital innovation capacity	0.2363***	0.2361***	0.2164***	0.1966***	0.1981***	0.1860***
	(0.035)	(0.035)	(0.035)	(0.032)	(0.032)	(0.032)
State ownership	-0.3558***	-0.8446***	-3.8211***	-0.2939***	-0.6920***	-2.6276***
	(0.112)	(0.200)	(0.854)	(0.096)	(0.176)	(0.770)
State ownership * Firm's digital transformation		0.2697***			0.2133***	
		(0.090)			(0.079)	
State ownership * Province digital innovation capacity			0.3428***			0.2308***
			(0.084)			(0.076)
Constant	-8.6369***	-8.6075***	-8.3045***	-12.1866***	-12.1769***	-12.0881***
	(1.113)	(1.114)	(1.116)	(1.024)	(1.024)	(1.024)
Observations	13712	13712	13712	13687	13687	13687
Number of firms	3179	3179	3179	3175	3175	3175
Log likelihood	-16184.26	-16179.80	-16175.34	-18742.19	-18738.50	-18737.41
Chi-square	1396.722	1404.843	1411.801	1917.162	1923.597	1924.701
Prob > Chi-square	0.000	0.000	0.000	0.000	0.000	0.000

Note: ***p < 0.01, **p < 0.05, *p < 0.1; robust standard errors are in parentheses. All models included industry and year dummies.

study, we find that firms with high state ownership tend to engage less in green innovation. We also find that such a negative impact of state ownership on green innovation is mitigated when the firm has a high level of digital transformation and operates in a province with a high level of digital innovation capacity. Our studies contribute to existing literature in the following ways.

First, our study contributes to green innovation literature by shedding new light on previous inconsistent findings. Given the increasing number of studies discussing SOEs' green innovation, the findings are still inconclusive (Bai et al., 2019; Pan et al., 2020; Wang & Jiang, 2021; Zhou et al., 2017). In this study, we first offer firm-level empirical evidence from China and find that high-level state ownership hinders green innovation. The reason for this finding is that managers in SOEs are often reluctant to promote green innovation, as it is highly risky and uncertain. Since SOE managers are often appointed based on their political experience but not professional expertise, they also have insufficient capacities to convert acquired resources into innovation output efficiently. More importantly, we introduce two different levels of digital factors into our discussion to further resolve this relationship. We find that the extent of negative impacts of state ownership on green innovation is not constant but contingent on whether the SOEs have a high level of digital transformation and operate in the provincial environment with a high degree of digital innovation capacity. The reason is that digital transformation can help increase managerial risk-taking, which is essential for green innovative practices. Using new digital technologies improves communication and resource utilization efficiency and helps reduce information asymmetry. Because of greater access to real-time and comprehensive information with digital transformation, managers in SOEs can improve green innovation willingness and capacity. This result is consistent with Xue et al. (2022), who also found that digital transformation significantly impacts green innovation in firms with state ownership. Such a significant moderating role of digital factors highlights the importance of how digitalization improves green innovation, casting light on the inconsistent relationship in the prior green innovation literature.

Second, our study also advances SOE innovation literature. Although SOE innovation has gained increasing attention over years (Benassi & Landoni, 2019; Chen et al., 2014; Genin et al., 2021; Jiang et al., 2020; Pan et al., 2020; Wang & Jiang, 2021; Wu et al., 2016; Zhou et al., 2017), the role of digitalization has been largely ignored (Feng et al., 2022). For example, Wang and Jiang (2021) found that state ownership increases innovation. In contrast, (Zhou et al., 2017) found a nonlinear relationship. Prior studies mostly investigate the institutional environment, industrial environments, firms' human resources practices, and manager characteristics as moderators (Wang & Jiang, 2021; Zhou et al., 2017). Our focus on digital factors adds to these existing studies by highlighting the importance of jointly considering digital factors that improve how much SOEs can innovate.

The results have several practical implications for government and managers. Since resources are scarce, the government should consider digital advances within SOEs and allocate resources such as developing digitalization-related funds, subsidies, and financial loans that can encourage SOEs to pay attention to digital transformation. This will encourage resource utilization efficiency and incentivize SOEs to conduct more green innovation. In addition, policymakers need to create a macro environment with a digitally favorable culture. For example, governments can invest resources in building the digital infrastructure. This includes consolidating infrastructure hardware and network system construction such as 5G base stations, cloud computing platforms, and big data systems. Government also can provide strong support for firms to adopt digital-related technologies through supported policies, subsidies, and innovation collaborative programs. In this way, the effect of SOEs' green innovation is amplified.

Additionally, SOE mangers should be well aware of the negative impact of state ownership on green innovation and also should take the initiative to increase R&D digital investments and improve firm-level digitalization. It is important to make long-term digital strategies, improve digital infrastructure, and adopt suitable digital tools that can effectively reduce information asymmetries as well as transaction costs. Also, short-term digital improvements within firms are also needed to catch up with the new era of digitalization with incremental change. These short-term improvements include

implementing basic digital tools (e.g., Dropbox), digitalizing paper-based processes, and offering digital training programs. In doing so, managers can have a more comprehensive understanding of the market and adjust their green innovation accordingly based on real-time information.

Limitations and Further Research

This study has several limitations. First, as with most studies, we use patent data to measure firms' green innovation. However, not all firms protect their assets and innovation performance with only patents. As legal systems for patent protection are often underdeveloped in emerging countries like China, many firms cannot apply for patents. It would be interesting for future studies to collect firsthand data and capture unpatented green innovation to understand our proposed relationships better. Also, as digital transformation is a rapidly evolving field, it is challenging to measure it from a static set of quantitative data. Future studies should develop more advanced measure to capture the dynamics of digital transformation. Second, our empirical findings are only based on the context of China. Further research in other emerging countries (e.g., India and Thailand) and developed countries is needed to validate our hypothesis and generate more robust findings based on multi-country comparisons. Third, further research on case-specific studies is also needed for a more comprehensive understanding of the relationship between state ownership and green innovation. Case-specific studies can provide detailed and vivid insights at the firm level, which can be more practical for SOE managers to take action for better green innovation using digital technology. Fourth, this study has considered only firm-level and province-level digital transformation. However, city-level digital transformation varies significantly in China, where government policies and digital development differ across cities. It is also meaningful to address how digital transformation moderates the relationship from city-level related factors.

CONFLICTS OF INTEREST

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

FUNDING STATEMENT

No funding was received for this work.

PROCESS DATES

Received: January 26, 2024, Revision: April 29, 2024, Accepted: May 10, 2024

CORRESPONDING AUTHOR

Correspondence should be addressed to Tong He; tong.he@xjtlu.edu.cn

REFERENCES

Aldieri, L., Carlucci, F., Vinci, C. P., & Yigitcanlar, T. (2019). Environmental innovation, knowledge spillovers and policy implications: A systematic review of the economic effects literature. *Journal of Cleaner Production*, *239*, 118051. 10.1016/j.jclepro.2019.118051

Alojail, M., & Khan, S. B. (2023). Impact of digital transformation toward sustainable development. *Sustainability (Basel)*, *15*(20), 14697. 10.3390/su152014697

Ardito, L., Messeni Petruzzelli, A., Pascucci, F., & Peruffo, E. (2019). Inter-firm R&D collaborations and green innovation value: The role of family firms' involvement and the moderating effects of proximity dimensions. *Business Strategy and the Environment*, *28*(1), 185–197. 10.1002/bse.2248

Bai, Y., Song, S., Jiao, J., & Yang, R. (2019). The impacts of government R&D subsidies on green innovation: Evidence from Chinese energy-intensive firms. *Journal of Cleaner Production*, *233*, 819–829. 10.1016/j.jclepro.2019.06.107

Bansal, P., & Roth, K. (2000). Why companies go green: A model of ecological responsiveness. *Academy of Management Journal*, *43*(4), 717–736. 10.2307/1556363

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, *17*(1), 99–120. 10.1177/014920639101700108

Baumgartner, C., Hartl, E., & Hess, T. (2021). *New workplace, new mindset: Empirical case studies on the interplay between digital workplace and organizational culture*. In F. Ahlemann, R. Schütte, & S. Sieglitz (Eds.), Lecture notes in information systmes and organisation: Vol. 46. Innovation through information systems and organisation (Vol. 3, pp. 91-107). Springer. 10.1007/978-3-030-86800-0_7

Benassi, M., & Landoni, M. (2019). State-owned enterprises as knowledge-explorer agents. *Industry and Innovation*, *26*(2), 218–241. 10.1080/13662716.2018.1529554

Berrone, P., Fosfuri, A., Gelabert, L., & Gomez-Mejia, L. R. (2013). Necessity as the mother of 'green' inventions: Institutional pressures and environmental innovations. *Strategic Management Journal*, *34*(8), 891–909. 10.1002/smj.2041

Caballero, R., Olmos, R., & Martinez, N. (2022). Digital maturity level in small and medium-sized enterprises in Panama. *The 2022 8th International Engineering,Sciences and Technology Conference (IESTEC).*

Cameron, A. C., & Trivedi, P. K. (2009). *Microeconometrics using stata*. Stata press.

Cao, X., Cumming, D., & Zhou, S. (2020). State ownership and corporate innovative efficiency. *Emerging Markets Review*, *44*, 100699. 10.1016/j.ememar.2020.100699

Cardinali, P. G., & De Giovanni, P. (2022). Responsible digitalization through digital technologies and green practices. *Corporate Social Responsibility and Environmental Management*, *29*(4), 984–995. 10.1002/csr.2249

Chen, V. Z., Li, J., Shapiro, D. M., & Zhang, X. (2014). Ownership structure and innovation: An emerging market perspective. *Asia Pacific Journal of Management*, *31*(1), 1–24. 10.1007/s10490-013-9357-5

Chen, X., Despeisse, M., & Johansson, B. (2020). Environmental sustainability of digitalization in manufacturing: A review. *Sustainability (Basel)*, *12*(24), 10298. 10.3390/su122410298

Chen, Y. (2020). Improving market performance in the digital economy. *China Economic Review*, *62*, 101482. 10.1016/j.chieco.2020.101482

Chen, Y.-S. (2008). The driver of green innovation and green image – green core competence. *Journal of Business Ethics*, *81*(3), 531–543. 10.1007/s10551-007-9522-1

Chen, Y.-S., Lai, S.-B., & Wen, C.-T. (2006). The influence of green innovation performance on corporate advantage in Taiwan. *Journal of Business Ethics*, *67*(4), 331–339. 10.1007/s10551-006-9025-5

Chen, Z., Xiao, Y., & Jiang, K. (2023). The impact of tax reform on firms' digitalization in China. *Technological Forecasting and Social Change*, *187*, 122196. 10.1016/j.techfore.2022.122196

Cheng, C. C. J. (2020). Sustainability orientation, green supplier involvement, and green innovation performance: Evidence from diversifying green entrants. *Journal of Business Ethics*, *161*(2), 393–414. 10.1007/s10551-018-3946-7

Cheng, C. C. J., Yang, C., & Sheu, C. (2014). The link between eco-innovation and business performance: A Taiwanese industry context. *Journal of Cleaner Production*, *64*, 81–90. 10.1016/j.jclepro.2013.09.050

Choi, S. B., Lee, S. H., & Williams, C. (2011). Ownership and firm innovation in a transition economy: Evidence from China. *Research Policy*, *40*(3), 441–452. 10.1016/j.respol.2011.01.004

Chrisman, J. J., & Patel, P. C. (2012). Variations in R&D investments of family and nonfamily firms: Behavioral agency and myopic loss aversion perspectives. *Academy of Management Journal*, *55*(4), 976–997. 10.5465/amj.2011.0211

Commission, E. (2016). State-owned enterprises in the EU: Lessons learnt and ways forward in a post-crisis context. *European Economy Institutional Papers,* 31.

Cui, J., Dai, J., Wang, Z., & Zhao, X. (2022). Does environmental regulation induce green innovation? A panel study of Chinese listed firms. *Technological Forecasting and Social Change*, *176*, 121492. 10.1016/j.techfore.2022.121492

Dangelico, R. M., & Pujari, D. (2010). Mainstreaming green product innovation: Why and how companies integrate environmental sustainability. *Journal of Business Ethics*, *95*(3), 471–486. 10.1007/s10551-010-0434-0

Du, J., Shen, Z., Song, M., & Zhang, L. (2023a). Nexus between digital transformation and energy technology innovation: An empirical test of A-share listed enterprises. *Energy Economics*, *120*, 106572. 10.1016/j.eneco.2023.106572

Fang, M., Nie, H., & Shen, X. (2023). Can enterprise digitization improve ESG performance? *Economic Modelling*, *118*, 106101. 10.1016/j.econmod.2022.106101

Feng, H., Wang, F., Song, G., & Liu, L. (2022). Digital transformation on enterprise green innovation: Effect and transmission mechanism. *International Journal of Environmental Research and Public Health*, *19*(17), 10614. 10.3390/ijerph191710614 36078329

Genin, A. L., Tan, J., & Song, J. (2021). State governance and technological innovation in emerging economies: State-owned enterprise restructuration and institutional logic dissonance in China's high-speed train sector. *Journal of International Business Studies*, *52*(4), 621–645. 10.1057/s41267-020-00342-w

Gong, C., & Ribiere, V. (2021). Developing a unified definition of digital transformation. *Technovation*, *102*, 102217. 10.1016/j.technovation.2020.102217

Gu, J., Shi, X., Wang, P., & Xu, X. (2022). Examining the impact of upstream and downstream relationship stability and concentration on firms' financial performance. *Journal of Business Research*, *141*, 229–242. 10.1016/j.jbusres.2021.12.018

Guo, D., Guo, Y., & Jiang, K. (2016). Government-subsidized R&D and firm innovation: Evidence from China. *Research Policy*, *45*(6), 1129–1144. 10.1016/j.respol.2016.03.002

Horbach, J. (2008). Determinants of environmental innovation – New evidence from German panel data sources. *Research Policy*, *37*(1), 163–173. 10.1016/j.respol.2007.08.006

Huang, X., Zhou, J., Zhou, Y., & Xu, Y. (2022). Digital economy's spatial implications on urban innovation and its threshold: Evidence from China. *Complexity*, *2022*, 1–25. 10.1155/2022/3436741

Huang, Z., Liao, G., & Li, Z. (2019). Loaning scale and government subsidy for promoting green innovation. *Technological Forecasting and Social Change*, *144*, 148–156. 10.1016/j.techfore.2019.04.023

Jaffe, A. B., Newell, R. G., & Stavins, R. N. (2005). A tale of two market failures: Technology and environmental policy. *Ecological Economics*, *54*(2-3), 164–174. 10.1016/j.ecolecon.2004.12.027

Jefferson, G., Hu, A. G. Z., Guan, X., & Yu, X. (2003). Ownership, performance, and innovation in China's large- and medium-size industrial enterprise sector. *China Economic Review*, *14*(1), 89–113. 10.1016/S1043-951X(03)00003-8

Na, Huang, K. G., & Zhang, C. M. (2019). Public governance, corporate governance, and firm innovation: An examination of state-owned enterprises. *Academy of Management Journal*, *62*(1), 220–247. 10.5465/amj.2016.0543

Jiang, W., Wang, A. X., Zhou, K. Z., & Zhang, C. (2020). Stakeholder relationship capability and firm innovation: A contingent analysis. *Journal of Business Ethics*, *167*(1), 111–125. 10.1007/s10551-019-04161-4

Karimi Takalo, S., Sayyadi Tooranloo, H., & Shahabaldini Parizi, Z. (2021). Green innovation: A systematic literature review. *Journal of Cleaner Production*, *279*, 122474. 10.1016/j.jclepro.2020.122474

Kassinis, G., & Vafeas, N. (2006). Stakeholder pressures and environmental performance. *Academy of Management Journal*, *49*(1), 145–159. 10.5465/amj.2006.20785799

Kemp, R., Arundel, A., & Smith, K. (2001). Survey indicators for environmental innovation [Paper presented to conference]: *Towards environmental innovation systems*, 27-29 Sept 2001, Garmisch Partenkirchen, GermanyGarmisch-Partenkirchen.

Kim, H., Kim, H., & Lee, P. M. (2008). Ownership structure and the relationship between financial slack and R&D investments: Evidence from Korean firms. *Organization Science*, *19*(3), 404–418. 10.1287/orsc.1080.0360

Kuo, C.-C., Shyu, J. Z., & Ding, K. (2019). Industrial revitalization via industry 4.0 – A comparative policy analysis among China, Germany and the USA. *Global Transitions*, *1*, 3–14. 10.1016/j.glt.2018.12.001

Lazzarini, S. G., Mesquita, L. F., Monteiro, F., & Musacchio, A. (2021). Leviathan as an inventor: An extended agency model of state-owned versus private firm invention in emerging and developed economies. *Journal of International Business Studies*, *52*(4), 560–594. 10.1057/s41267-020-00327-9

Lee, K.-H., & Min, B. (2015). Green R&D for eco-innovation and its impact on carbon emissions and firm performance. *Journal of Cleaner Production*, *108*, 534–542. 10.1016/j.jclepro.2015.05.114

Li, H., & Zhang, Y. (2007). The role of managers' political networking and functional experience in new venture performance: Evidence from China's transition economy. *Strategic Management Journal*, *28*(8), 791–804. 10.1002/smj.605

Li, S., & Lu, J. W. (2020). A dual-agency model of firm CSR in response to institutional pressure: Evidence from Chinese publicly listed firms. *Academy of Management Journal*, *63*(6), 2004–2032. 10.5465/amj.2018.0557

Li, W., & Lu, X. (2016). Institutional interest, ownership type, and environmental capital expenditures: Evidence from the most polluting Chinese listed firms. *Journal of Business Ethics*, *138*(3), 459–476. 10.1007/s10551-015-2616-2

Li, W. H., Luo, J., De Sisto, M., & Bartram, T. (2021). Born to rebel? The owner birth order and R&D investments in Chinese family firms. *Journal of Product Innovation Management*, *38*(4), 421–446. 10.1111/jpim.12584

Li, Y., Dai, J., & Cui, L. (2020). The impact of digital technologies on economic and environmental performance in the context of industry 4.0: A moderated mediation model. *International Journal of Production Economics*, *229*, 107777. 10.1016/j.ijpe.2020.107777

Liu, J., Zhou, K., Zhang, Y., & Tang, F. (2023). The effect of financial digital transformation on financial performance: The intermediary effect of information symmetry and operating costs. *Sustainability (Basel)*, *15*(6), 5059. 10.3390/su15065059

Liu, L., Zhang, Y., Gong, X., Li, M., Li, X., Ren, D., & Jiang, P. (2022). Impact of digital economy development on carbon emission efficiency: A spatial econometric Analysis based on Chinese provinces and cities. *International Journal of Environmental Research and Public Health*, *19*(22), 14838. 10.3390/ijerph19221483836429556

Liu, W., De Sisto, M., & Li, W. H. (2021). How does the turnover of local officials make firms more charitable? A comprehensive analysis of corporate philanthropy in China. *Emerging Markets Review*, *46*, 100748. 10.1016/j.ememar.2020.100748

Liu, W., Li, W. H., Yang, J. Y., & Zheng, L. J. (2024). Geographical proximity, foreign presence and domestic firm innovation: The micro-level evidence. *Regional Studies*, *58*(4), 787–804. 10.1080/00343404.2023.2249048

Liu, W., Shao, X., De Sisto, M., & Li, W. H. (2021). A new approach for addressing endogeneity issues in the relationship between corporate social responsibility and corporate financial performance. *Finance Research Letters*, *39*, 101623. 10.1016/j.frl.2020.101623

Liu, W., Xu, Y., Fan, D., Li, Y., Shao, X. F., & Zheng, J. (2021). Alleviating corporate environmental pollution threats toward public health and safety: The role of smart city and artificial intelligence. *Safety Science*, *143*, 105433. 10.1016/j.ssci.2021.105433

Liu, Y., Dong, J., Ying, Y., & Jiao, H. (2021). Status and digital innovation: A middle-status conformity perspective. *Technological Forecasting and Social Change*, *168*, 120781. 10.1016/j.techfore.2021.120781

Liu, Z., Li, X., Peng, X., & Lee, S. (2020). Green or nongreen innovation? Different strategic preferences among subsidized enterprises with different ownership types. *Journal of Cleaner Production*, *245*, 118786. 10.1016/j.jclepro.2019.118786

Lu, Y., Xu, C., Zhu, B., & Sun, Y. (2023b). Digitalization transformation and ESG performance: Evidence from China. *Business Strategy and the Environment*, *33*(2), 352–368. 10.1002/bse.3494

Ma, W., Zhang, R., & Chai, S. (2019). What drives green innovation? A game theoretic analysis of government subsidy and cooperation contract. *Sustainability (Basel)*, *11*(20), 5584. 10.3390/su11205584

Marquis, C., & Qian, C. (2014). Corporate social responsibility reporting in China: Symbol or substance? *Organization Science*, *25*(1), 127–148. 10.1287/orsc.2013.0837

Martins, E. C., & Terblanche, F. (2003). Building organisational culture that stimulates creativity and innovation. *European Journal of Innovation Management*, *6*(1), 64–74. 10.1108/14601060310456337

Matos, S., Viardot, E., Sovacool, B. K., Geels, F. W., & Xiong, Y. (2022). Innovation and climate change: A review and introduction to the special issue. *Technovation*, *117*, 102612. 10.1016/j.technovation.2022.102612

Meng, S., Su, H., & Yu, J. (2022). Digital transformation and corporate social performance: How do board independence and institutional ownership matter? *Frontiers in Psychology*, *13*, 915583. 10.3389/fpsyg.2022.91558335693524

Orsatti, G., Quatraro, F., & Pezzoni, M. (2020). The antecedents of green technologies: The role of team-level recombinant capabilities. *Research Policy*, *49*(3), 103919. 10.1016/j.respol.2019.103919

Pan, X., Chen, X., Sinha, P., & Dong, N. (2020). Are firms with state ownership greener? An institutional complexity view. *Business Strategy and the Environment*, *29*(1), 197–211. 10.1002/bse.2358

Peattie, K. (2008). *The marketing book*. Routledge., 10.1016/B978-0-7506-8566-5.50032-7

Peng, M. W., & Luo, Y. (2000). Managerial ties and firm performance in a transition economy: The nature of a micro-macro link. *Academy of Management Journal*, *43*(3), 486–501. 10.2307/1556406

Pfaff, Y. M., Wohlleber, A. J., Münch, C., Küffner, C., & Hartmann, E. (2023). How digital transformation impacts organizational culture – A multi-hierarchical perspective on the manufacturing sector. *Computers & Industrial Engineering*, *183*, 109432. 10.1016/j.cie.2023.109432

Qu, G., & Pan, X. (2023). Not all green innovations are equally green: State ownership, green innovation generality and contingencies. *Business Ethics, the Environment & Responsibility*, *32*(4), 1532–1546. 10.1111/beer.12577

Ramamurti, R. (2000). A multilevel model of privatization in emerging economies. *Academy of Management Review*, *25*(3), 525–550. 10.2307/259308

Ren, S., Huang, M., Liu, D., & Yan, J. (2022). Understanding the impact of mandatory CSR disclosure on green innovation: Evidence from Chinese listed firms. *British Journal of Management*, *36*, 576–592.

Rennings, K. (2000). Redefining innovation – eco-innovation research and the contribution from ecological economics. *Ecological Economics*, *32*(2), 319–332. 10.1016/S0921-8009(99)00112-3

Ryan, T. P. (1997). *Modern Regression Analysis*. John Willey and Sons.

Schiederig, T., Tietze, F., & Herstatt, C. (2012). Green innovation in technology and innovation management – an exploratory literature review. *R & D Management*, *42*(2), 180–192. 10.1111/j.1467-9310.2011.00672.x

Tan, J. (2002). Impact of ownership type on environment–strategy linkage and performance: Evidence from a transitional economy. *Journal of Management Studies*, *39*(3), 333–354. 10.1111/1467-6486.00295

Tian, G., Li, B., & Cheng, Y. (2022). Does digital transformation matter for corporate risk-taking? *Finance Research Letters*, *49*, 103107. 10.1016/j.frl.2022.103107

Tihanyi, L., Aguilera, R. V., Heugens, P., van Essen, M., Sauerwald, S., Duran, P., & Turturea, R. (2019). State ownership and political connections. *Journal of Management*, *45*(6), 2293–2321. 10.1177/0149206318822113

Wagner, M. (2007). On the relationship between environmental management, environmental innovation and patenting: Evidence from German manufacturing firms. *Research Policy*, *36*(10), 1587–1602. 10.1016/j.respol.2007.08.004

Wang, K., & Jiang, W. (2021). State ownership and green innovation in China: The contingent roles of environmental and organizational factors. *Journal of Cleaner Production*, *314*, 128029. 10.1016/j.jclepro.2021.128029

Wang, R., Wijen, F., & Heugens, P. P. (2018). Government's green grip: Multifaceted state influence on corporate environmental actions in China. *Strategic Management Journal*, *39*(2), 403–428. 10.1002/smj.2714

Wang, X., Li, Y., Tian, L., & Hou, Y. (2023). Government digital initiatives and firm digital innovation: Evidence from China. *Technovation*, *119*, 102545. 10.1016/j.technovation.2022.102545

Wen, H., Zhong, Q., & Lee, C.-C. (2022). Digitalization, competition strategy and corporate innovation: Evidence from Chinese manufacturing listed companies. *International Review of Financial Analysis*, *82*, 102166. 10.1016/j.irfa.2022.102166

Wooldridge, J. M. (1999). Distribution-free estimation of some nonlinear panel data models. *Journal of Econometrics*, *90*(1), 77–97. 10.1016/S0304-4076(98)00033-5

Wu, J., Wang, C., Hong, J., Piperopoulos, P., & Zhuo, S. (2016). Internationalization and innovation performance of emerging market enterprises: The role of host-country institutional development. *Journal of World Business*, *51*(2), 251–263. 10.1016/j.jwb.2015.09.002

Xia, L., Gao, S., Wei, J., & Ding, Q. (2022). Government subsidy and corporate green innovation - Does board governance play a role? *Energy Policy*, *161*, 112720. 10.1016/j.enpol.2021.112720

Xie, X., Huo, J., & Zou, H. (2019). Green process innovation, green product innovation, and corporate financial performance: A content analysis method. *Journal of Business Research*, *101*, 697–706. 10.1016/j.jbusres.2019.01.010

Xu, J., & Li, W. (2022). The impact of the digital economy on innovation: New evidence from panel threshold model. *Sustainability (Basel)*, *14*(22), 15028. 10.3390/su142215028

Xu, Y., Liu, W., He, T., & Tsai, S. B. (2024). Buzzword or fuzzword: An event study of the metaverse in the Chinese stock market. *Internet Research*, *34*(1), 174–194. 10.1108/INTR-07-2022-0526

Xu, Y., Liu, W., Zhou, J., Wong, L., & Yue, X. G. (2022). Does the agenda-setting effect always work? The moderating role of institution informatization. [JOEUC]. *Journal of Organizational and End User Computing*, *34*(8), 1–14. 10.4018/JOEUC.315638

Xue, L., Zhang, Q., Zhang, X., & Li, C. (2022). Can digital transformation promote green technology innovation? *Sustainability (Basel)*, *14*(12), 7497. 10.3390/su14127497

Yang, X., Wang, H., & Zhou, X. (2023). Geographic distance and state's grip: Information asymmetry, state inattention, and firm implementation of state policy. *Journal of Management*, 01492063231197390. 10.1177/01492063231197390

Yao, S., Pan, Y., Wang, L., Sensoy, A., & Cheng, F. (2023). Building eco-friendly corporations: The role of minority shareholders. *Journal of Business Ethics*, *182*(4), 933–966. 10.1007/s10551-022-05291-y

Zeng, H., Ran, H., Zhou, Q., Jin, Y., & Cheng, X. (2022). The financial effect of firm digitalization: Evidence from China. *Technological Forecasting and Social Change*, *183*, 121951. 10.1016/j.techfore.2022.121951

Zhang, C., Zhou, B., & Tian, X. (2022). Political connections and green innovation: The role of a corporate entrepreneurship strategy in state-owned enterprises. *Journal of Business Research*, *146*, 375–384. 10.1016/j.jbusres.2022.03.084

Zhao, S. L., Cacciolatti, L., Lee, S. H., & Song, W. (2015). Regional collaborations and indigenous innovation capabilities in China: A multivariate method for the analysis of regional innovation systems. *Technological Forecasting and Social Change*, *94*, 202–220. 10.1016/j.techfore.2014.09.014

Zhou, K. Z., Gao, G. Y., & Zhao, H. (2017). State ownership and firm innovation in China: An integrated view of institutional and efficiency logics. *Administrative Science Quarterly*, *62*(2), 375–404. 10.1177/0001839216674457

Renhao Liu is a doctoral student at the School of Business, Sun Yat-sen University.

Beifan Zhang is a PhD candidate in Management at the University of Technology Sydney.

Tong He is an Assistant Professor at Entrepreneur College, Xi'an Jiaotong Liverpool University.

Youqing Fan is an Associate Professor at the Western Sydney University. ORCID: https://orcid.org/0000-0001-9508-5411

Shuang Li is a PhD candidate in entrepreneurship and innovation at the University of Warwick.