

Digital platform capability, environmental innovation quality, and firms' competitive advantage: The moderating role of environmental uncertainty

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ABSTRACT

In the context of the "Internet plus" era, exploring whether digital platforms can enhance firms' competitive advantage, and the internal mechanism of this potential relationship, is of great significance. Based on the theory of dynamic capabilities, this study examines the impact of digital platform's capability on firms' competitive advantage, as well as the mediating effect of environmental innovation quality and the moderating effect of environmental uncertainty. We selected 242 firms in the Chinese manufacturing industry as the sample and tested the model using multiple regression methods. The results show that digital platform capability has a significant positive impact on firms' competitive advantage, environmental innovation quality plays a partial mediating role between digital platform capability and firms' competitive advantage, and the effect of digital platform capability on firms' environmental innovation quality is negatively moderated by environmental uncertainty. The research reveals the mechanism of interaction between digital platform capability and competitive advantage, which can aid firms in building digital platforms, and improve the quality of their environmental innovation and their competitive advantage.

1. Introduction

With the acceleration of industrialization and the intensification of practical contradictions, such as aging populations, environmental awareness, and economic environment uncertainty, the competitive advantages of manufacturing firms generated by low-cost labor and extensive production models are gradually dissipating (Banister et al., 2012; Tan et al., 2022; Zhao et al., 2022). The question of how to achieve high-quality development while maintaining core competitiveness has become a key challenge for manufacturing firms, which both governments and scholars urgently need to solve. Scholars have thus gradually explored the application of emerging technologies, such as digital platforms (Sarwar et al., 2023; Wang et al., 2023b), sustainable production and operation, including environmental innovation (Cheng et al., 2023; Quan et al., 2023), and the enormous potential of such disruptive approaches as the integration of firms' upstream and downstream ecosystem systems in the industrial chain in building core competitive advantages (Dong et al., 2023). In the context of firms' digital transformation trend, and increasing number of firms have

effectively integrated digital technology (Sia et al., 2021). The digital economy has gradually become the main driving force for the development of the global economy, following the agricultural and industrial economies, bringing new opportunities to enhance the competitiveness of manufacturing firms (Cozzolino et al., 2021; Sarwar et al., 2023; Tian et al., 2023).

As the main carrier and organizational form of the digital economy, digital platforms, based on multi-agent participation and cross-boundary interaction, have scalability, extensibility, and complementary functions (Tiwana, 2014; Karhu et al., 2018), provide new ways to create value for stakeholders (Kamal et al., 2022), and help firms obtain valuable external resources (Wang et al., 2023b) to achieve sustainable innovation (Chen et al., 2022a) and establish a core competitive advantage (Cenamor et al., 2019; Ahmed et al., 2022). Digital platform capability can be defined as an organization's ability to use the most advanced digital tools and technologies as its competitive instruments based on its digital platforms; it is considered a higher-order dynamic capability (Cenamor et al., 2019), which helps the firm effectively coordinate resources and achieve optimal operation (Karimi and Walter,

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2015). It is the result of a firm's effort to enrich its strategies in response to competitive pressures (Li et al., 2016). Realizing the enormous potential of digital platforms for firms' growth, scholars have conducted preliminary explorations on the consequences of their capabilities, such as innovation (Wang et al., 2022, 2023b; Wang et al., 2023b) and performance (Cenamor et al., 2019; Sarwar et al., 2023), and have further explored their internal mechanisms, including dynamic capabilities (Cenamor et al., 2019) and intellectual capital (Ahmed et al., 2022). Nonetheless, some areas still require further exploration.

First, given that the construction of firms' digital platforms is still in the exploration and adaptation stage, their inherent complexity and unknown future applications determine their heavy reliance on resources and funds, and the numerous cases of failed digital platform construction have deepened the "wait-and-see" attitude of firms (Wang et al., 2023b). If they cannot obtain significant expected returns, firms tend to refuse to adopt this strategy. However, the existing literature provides differentiated research conclusions on the impact of firms' digital platform capability (Liu et al., 2023). If the impact on firms' innovation and competitive advantage cannot be explored clearly and effectively, confusion will prevail in current theoretical research in this field and lay the foundation for failure in the construction of firm-related digital platforms (De Reuver et al., 2018; Sarwar et al., 2023). Second, previous studies have overlooked the crucial role of sustainable-development factors, such as the quality of firms' environmental innovation in the internal path of their digital platform capabilities and competitive advantages. Although scholars have acknowledged that simply adopting digital platforms cannot directly help firms achieve success, the acquisition of a competitive advantage is based on firms' ability to flexibly use such platforms to optimize and deploy their existing strategies (Teece, 2018; Cenamor et al., 2019; Wang et al., 2023b). However, existing research has focused more heavily on economic returns (Sarwar et al., 2023), and research on the internal path appears to be too simplistic. Indeed, it has generally studied the transmission effects of such factors as dynamic capabilities (Cenamor et al., 2019) without specifying the implementation path, which has low practical utility for firms. At the same time, with the gradual deterioration of the natural environment, the demand for "harmonious coexistence between humans and nature" as a development model is particularly urgent in current times. Sustainable approaches, such as substantive environmental innovation, have become the focus of stakeholders' attention and largely determine firms' core competitive advantage (Porter and Van der Linde, 1995; Buysse and Verbeke, 2003; Albitar et al., 2023). In addition, with the development of firms' digital technology applications, the balance effect of digital platforms between firms' economic benefits and environmental goals is highlighted (Li et al., 2020; Reuter, 2022). The path for firms to improve the quality of environmental innovation based on their digital platform capability, and ultimately obtain competitive advantages, may explain the internal mechanism of establishing competitive advantages for firms at present. Finally, previous scholars have focused on the direct effects or internal pathways of digital platform capability on firms' related behavior, neglecting the possible boundaries of external factors (Sarwar et al., 2023; Wang et al., 2023b). With the intensification of global market competition, the external environment has become increasingly uncertain and unpredictable, and can significantly impact corporate behavior (Wang et al., 2021). The lack of research on external environmental factors simplifies the complex relationship between the capabilities of firms' digital platforms and their outcomes, and may produce misleading research results (Ahmed et al., 2022).

To fill the gaps in the existing research, and thus enhance the establishment of competitive advantages for firms, we raised three important questions and conducted empirical tests: (1) Can digital platform capability promote firms' competitive advantage? (2) What is the specific internal path between firms' digital platform capability and competitive advantages? and (3) What factors affect this transmission pathway?

The contributions of this study are as follows. First, it expands the effective antecedents of the establishment of a new competitive advantage for firms in the context of the "Internet plus" era, links firms' digital platform capability with their meaningful and practical advantages, and confirms the positive impact of firms' digital platform capability on the establishment of competitive advantages (Mikalef and Pateli, 2017; Ahmed et al., 2022). The empirical results clarify the contradictory findings of previous studies and provide a useful supplement to core competition theory (Liu et al., 2023). Second, this study incorporates environmental innovation quality, a key concern of stakeholders (e.g., consumers and governments) in the context of the current "digital economy" and "sustainable development" era, into the internal path of establishing competitive advantages for firms. Our results can serve to refine the specific transmission channels of the impact of dynamic capabilities on competitive advantages, not only enriching the relevant research on dynamic capabilities theory, but also expanding the "equipment library" of firms' strategic choices (Chen et al., 2022b; Wang et al., 2023b). Finally, this study lists environmental uncertainty as a potential influencing factor in the aforementioned transmission path and represents a new attempt to include external environmental factors as boundary conditions for digital platform capability's impact on firms' competitive advantage. The empirical results enrich the theoretical research on the impact of environmental uncertainty on corporate strategic deployment (Ahmed et al., 2022) and reveal a new research domain on the impact of digital platform capability on corporate outcomes.

The remainder of the article is structured as follows. Section 2 lays out our research hypotheses based on relevant theories and a background literature review. Section 3 describes the research methods used to test these hypotheses. Section 4 presents the results of our data analysis, and Section 5 elaborates on the conclusions, implications, and limitations of the study.

2. Theoretical background and hypotheses

How firms obtain and maintain competitive advantages is a fundamental issue in the field of strategic management (Barnett and McKendrick, 2004; Newbert, 2008; Wang and Gao, 2021; Nayak et al., 2022). Previous research has focused on the resource-based perspective, emphasizing that firms' valuable, scarce, imutable, and irreplaceable resources are the sources of competitive advantage (Barney, 1991; Newbert, 2008). However, scholars have gradually discovered that owning these specific resources insufficient for maintaining a competitive advantage in the current fierce and constantly-changing business environment, and even firms with similar resources may exhibit differences in behavior (Eisenhardt and Martin, 2000; Wang, 2014). In this context, the dynamic capability theory was proposed by Teece et al. (1997) as an extension of the resource-based view, and gradually became an internal theoretical perspective for scholars to explain how firms maintain competitive advantages and achieve excellent long-term performance in turbulent environments (Helfat and Raubitschek, 2018; Sousa-Zomer et al., 2020).

The acceleration of technological iteration, digital transformation, and increasing regulatory pressure on sustainable development have forced firms to face more tempestuous and uncertain external environments (Wang et al., 2023b). In this context, the continuous optimization of resource allocation has become a key antecedent for firms to gain a competitive advantage (Tiberius et al., 2021). Dynamic capabilities describe a firm's ability to perceive opportunities and threats, seize the former, and reconfigure both tangible and intangible resources within and outside the firm (Teece, 2007). With the rapid development and popularization of digital technology, scholars have extended the dynamic capabilities of firms and studied the relationship between such capabilities and firms' behavioral outcomes (Sarwar et al., 2023; Wang et al., 2023b). Digital dynamic capabilities help firms perceive constantly-changing market demands and the latest developments in

technological iterations, continuously adjust resources to achieve optimal strategic allocation, and establish their own capabilities to capture a constant stream of possible opportunities (Teece, 2018). This can provide them with a solid competitive advantage that does not easily disappear in a fast-paced and uncertain dynamic digital environment (Chen et al., 2022b).

2.1. The impact of digital platform capability on firms' competitive advantage

The competitive advantage theory is rooted in the theory of competition, which assumes that competitors and competitive prospects are prerequisites (Bain, 1956). Competitive advantage is manifested as a firm having stronger performance capabilities—typically obtained through low-cost and product differentiation methods—than its market competitors (Porter, 1985). Moreover, research on the resource-based view suggests that competitive advantage comes from the key resources and capabilities controlled by firms (Barney, 1991). However, due to rapid environmental changes, inherent resources may continue to depreciate or fail (Teece and Pisano, 1994) and are easily imitated by competitors, making it difficult for resources themselves to directly help firms maintain their competitive advantage (Wang et al., 2015; Mikalef and Pateli, 2017). Efficient and sustainable allocation, and the ability to integrate and utilize resources, have become vital for firms to establish sustainable competitive advantages (Sirmon et al., 2011; Tiberius et al., 2021).

In this context, the dynamic capabilities theory has gradually become the theoretical basis for explaining firms' acquisition of competitive advantages. Within the theory, dynamic capability refers to a firm's ability to strategically reconfigure its operational capabilities and internal and external resources, in order to lay out and cultivate new "cores" with which to adapt to ever-changing market business needs (Teece, 2007; Lütjen et al., 2019). This helps a firm to achieve and maintain high performance and competitive advantages, and its utility is more significant in dynamic and unpredictable market environments (Mikalef and Pateli, 2017; Chen et al., 2022b). At the same time, digital platform capability is the ability of firms to break organizational boundaries, acquire, integrate, allocate, and reconstruct resources, exchange information resources with external firms to achieve platform integration, and internalize the most advanced digital technologies and tools into their own competitive means (Cenamor et al., 2019; Li and Chan, 2019).

We believe that digital platform capabilities can help firms gain competitive advantages for the following reasons. Firstly, as a way for firms to convert digital platform resources into digital capabilities, digital platform capabilities can enhance the openness of external interactions through standardized interfaces with other participating entities, promote the exchange and collaboration of external resources, capabilities, actions, and goals (Helfat and Campo-Rembado, 2016), and help firms rapidly and cheaply access external heterogeneous resources, thereby enhancing their competitive advantage. Secondly, digital platform capabilities also include the ability to streamline business processes, identify environmental changes, make quick decisions, and implement strategies (Cenamor et al., 2019; Dubey et al., 2020). In so doing, firms with excellent digital platform capabilities can quickly execute their strategic decisions and plans to respond to internal and external environmental changes, and thus hold competitive advantages in dynamic market environments. Once again, digital platforms can provide unique and effective predictive information in terms of product information, consumer trends, and other aspects (Warner and Wäger, 2019). Firms with high-level digital platform capabilities can take leading market positions earlier than their competitors, thus establishing their first-mover, and subsequent competitive, advantages. Finally, as a strategic and dematerialization tool for firms, high-level digital platform capabilities can not only bring significant cost reductions, but also increase the economic income of firms (Ahmed et al., 2022),

thereby enhancing their competitive advantage. Therefore, we propose the following hypothesis.

H1. Digital platform capability has a positive impact on firms' competitive advantage.

2.2. The impact of digital platform capability on firms' environmental innovation quality

In the context of the digital economy era, digitization has evolved from an initial technical matter to a strategic management issue that affects the core value proposition of firms (Li et al., 2018), who are further accelerating the construction of their digital platform capabilities (Cenamor et al., 2019; Wang et al., 2023b). Digital platforms' inherent characteristics of flexibility, openness, and availability have increasingly made them the center of firms' innovation activities (Rai et al., 2019). Having high-level digital platform capabilities can help improve firms' online communication, internal and external collaboration, and marketing level, as well as achieve low-cost and cost-effective resource expansion, increase opportunities for identifying and integrating key shared knowledge, and efficiently create value through such strategies as innovation (Helfat and Raubitschek, 2018; Teece, 2018).

According to existing theory, high-level digital platform capability promotes the improvement of a firm's environmental innovation quality for the following reasons. First, digital platform capability helps firms simplify business processes and achieve high levels of efficiency in strategic decision-making and implementation (Cenamor et al., 2019), enabling more agile and effective discovery and response to market demands (Teece, 2018; Ahmed et al., 2022). As society continues to develop, economic growth and efficiency are no longer the only focus of governments and entrepreneurs, with sustainable-development models having increasingly become new market demands (Horbach, 2008; Liao and Liu, 2021). Innovation—and especially its environmental variety—is seen as a key solution to the balance of social, environmental, and economic performance issues (Pan et al., 2019; Wang and Juo, 2021). As such, it has received significant attention from governments and scholars in various countries, and has brought new opportunities for the development of firms (Albitar et al., 2023; Bammens and Hünermund, 2023). With the continuous increase of pressure from government regulation and consumer supervision, the criticism of firms' strategic environmental innovation behavior has gained prominence. Substantive environmental innovation, that is, high-quality environmental innovation behavior, has significant benefits for firms and has become an effective way for them to grow steadily and respond to the needs of various stakeholders (Liao, 2020; Sha et al., 2022). Firms with high-level digital platform capability can seize the opportunities for high-quality environmental innovation behavior and adopt more substantive environmental innovation strategies. Second, due to the rapid iteration of technology and the limitations of their resources, firms are increasingly relying on external complementary resources to generate innovation (Pushpanathan and Elmquist, 2022). Compared to general innovation, the environmental innovation requires more complex and innovative resources and knowledge bases (Valero-Gil et al., 2023) and has dual externalities of knowledge and environment (Renning, 2000).

Digital platforms can help firms achieve rapid information exchanges and reduce information asymmetry and uncertainty, lower resource search and transaction costs, and integrate key shared knowledge (Teece, 2018). High-level digital platform capability allows firms to more effectively configure, arrange, and coordinate internal and external resources, and transform external information into internal knowledge resources (Helfat and Raubitschek, 2018; Cenamor et al., 2019). It can also strengthen close cooperation between firms (Caputo et al., 2022), weaken the inherent inhibitory effects of environmental innovation characteristics, and promote the implementation of high-quality environmental innovation actions. In addition, high-level digital platform capability can increase organizational flexibility and

reduce the inhibitory effect of dogmatic and rigid organizational structures on the knowledge value generated by such processes as knowledge transfer and sharing (Stojanović-Aleksić et al., 2019), thus promoting efficient and real-time sharing of resources (knowledge, etc.) across departments (Cenamor et al., 2019; Gupta and Bose, 2019), thus providing resource guarantees for high-level environmental innovation behaviors. Accordingly.

H2. Digital platform capability has a positive impact on the quality of firms' environmental innovation.

2.3. The impact of environmental innovation quality on firms' competitive advantage

Competitive advantage is a key issue in strategic management, and early research focused on the impact of such factors as key resources, business strategy, firm capability. However, with mounting social awareness, researchers have begun to explore the combination of a firm's competitive and social advantages, with the latter forming a stronger basis (Nayak et al., 2022). At the same time, environmental innovation has gradually become an important component of corporate strategy due to its key capabilities in fulfilling social responsibility and performance, and maintaining sustained competitive advantages (Huang and Li, 2017; Wang et al., 2023a).

The improvement of the quality of firms' environmental innovation can promote the acquisition of competitive advantages, mainly for the following reasons. Firstly, the Porter hypothesis suggests that environmental innovation can generate innovative compensation effects on the production costs of firms, compensate for economic losses caused by increased production costs, and even yield better economic benefits to firms (Porter and Van der Linde, 1995; Song et al., 2022). With society's increasing attention to the ecological environment, eco-products and -services have begun to attract increasing consumer attention and have demonstrated strong potential development capabilities in the market (Chang, 2011; Roespinoedji et al., 2019; Zhang and Zhu, 2019). The higher the quality of environmental innovation, the more customer attention can be attracted in comparison to a firm's competitors, and the easier it is to establish a sustained competitive advantage (Forsman, 2013). In addition, improving the environmental innovation quality is beneficial for firms to deeply analyze the market demand for ecological products and services, achieve positive feedback on environmental innovation, improve production efficiency and resource utilization, and enhance ecological benefits in competitive markets (Rosen, 2001; Pan et al., 2021). Secondly, compared to other forms, environmental innovation is more challenging, with no standardized evaluation criteria, a lack of benchmark enterprises with mature technology and experience, a long production process, and high uncertainty in costs and benefits (De Marchi, 2012; Hao et al., 2023). This serves to limit firms' development of environmental innovation behavior, thus making high-quality environmental innovation more prominent. In the future market competition, firms that take the lead in environmental innovation can not only maintain their leading positions, but they can also stimulate the improvement of their own environmental innovation efficiency, and output more eco-products and -services, thus hindering other firms from imitating or surpassing them (Pujari et al., 2003; Qiu et al., 2020). High-quality environmental innovation can enhance government environmental standards, establish new industry environmental norms, raise industry entry barriers, enter niche markets, and consolidate market position (Chen and Chang, 2013; Zameer et al., 2022), thereby maintaining high long-term competitiveness in dynamic competitive markets. Finally, high-quality environmental innovation can not only enhance the environmental management efficiency of firms, but also better meet the environmental expectations of stakeholders, enhance the reputation of firms, bring long-term economic and social benefits, and further safeguard their competitive advantages (Kuo et al., 2022). Therefore, we propose the following hypothesis.

H3. Environmental innovation quality has a positive impact on firms' competitive advantage.

2.4. The mediating role of environmental innovation quality

The potential role of digital platforms lies in their ability to enable agile and effective exploration of market demand to create excellent opportunities for firms. However, as the external environment of firms becomes increasingly turbulent, and market competition intensifies, simply adopting digital platforms cannot directly help firms achieve success. Furthermore, the acquisition of competitive advantages is based on the flexible use of digital platforms and the ability to optimize and deploy existing strategies (Teece, 2018; Cenamor et al., 2019; Wang et al., 2023b).

Based on dynamic capability theory and core competition theory, we believe that the quality of environmental innovation plays a mediating role between digital platform capability and firms' competitive advantages. On the one hand, digital platform capability has considerable advantages in information collection, interaction, cross-border integration of resources, and knowledge flow (Helfat and Raubitschek, 2018; Teece, 2018; Cenamor et al., 2019). This can effectively compensate for the inherent "defects" of environmental innovation behavior, such as dual externalities, long research and development cycles, and complex knowledge bases (Rennings, 2000), and promote the occurrence of high-quality environmental innovation behavior in firms. On the other hand, today's sustainable-development model has gradually become a mainstream demand of governments, society, and consumers (Albitar et al., 2023), and the turbulent market environment has further weakened the prominent role of resources in establishing competitive advantages (Wang, 2014). Due to its inherent "isolation mechanism," innovation has become a new key source of competitive advantages for firms (Chang, 2011). Due to its inherent complexity and long periodicity, high-quality environmental innovation is not easily imitated and surpassed by competitors in the short run, and it substantively responds to the market's demand for "ecology." It helps firms establish competitive barriers and gain market share, thereby promoting the establishment of a core competitive advantage (Zameer et al., 2022). Therefore, we propose the following hypothesis.

H4. The quality of environmental innovation plays a mediating role between digital platform capability and firms' competitive advantage.

2.5. The moderating role of environmental uncertainty

Firms are currently facing a more complex and turbulent external environment. The concept of environmental uncertainty was proposed by Milliken (1987), who believed that, in uncertain environments, it is impossible to know the probability of future events and accurately predict the outcome of decisions due to the lack of causally-related information. As one of the key issues in the current field of strategic management, environmental uncertainty can significantly impact the structure, strategic decisions, and behavioral outcomes of firms (Ghosh and Olsen, 2009; Eroglu and Hofer, 2014; Ahmed et al., 2022).

Choosing the right strategy lies at the core of the adaptation process between an organization and its environment (Verdu et al., 2012). The value creation of firms' digital platform capability often depends on firms' favorable external environment (Ahmed et al., 2022). We believe that, even with a high level of digital platform capability, firms may not achieve high-quality environmental innovation behavior under highly-uncertain external environmental conditions for the following reasons. First, the external environment is an important source of resources and information, and critically impacts investment behavior (Ghosh and Olsen, 2009). However, a highly-uncertain external environment can lead to information asymmetry and intensified market risks (Verdu et al., 2012), weakening the prominent role of firms' digital platform capability in information exchange, opportunity identification,

knowledge transfer, and other aspects, thereby increasing the difficulty of the information processing required from managers. For innovative projects that are difficult to predict and whose returns are challenging to judge, such as high-quality environmental innovation, firms tend to adopt a “wait-and-see” attitude (Bloom et al., 2007; Kim and Kung, 2017). Second, based on preventive motivation, amidst harsh and uncertain external environments, firms usually adopt more conservative investment strategies, reducing their investment in innovation activities and leaning towards higher-scale cash-flow guarantees (Almeida and Campello, 2007), whereas environmental innovation is a long-term investment activity with long cycles and high risks (De Marchi, 2012; Dou and Xu, 2021). In this context, firms reduce their environmental innovation behavior, especially for high-level more complex and costly environmental innovation, and may inject resources into other safer and profitable activities that digital platform capability can mine. Therefore, we propose the following hypothesis.

H5. The relationship between digital platform capability and the quality of firms’ environmental innovation is negatively moderated by environmental uncertainty.

Our research model is shown in Fig. 1.

3. Methods

3.1. Data sources

We obtained the data for this study through a questionnaire. After its design, we randomly selected 20 manufacturing industry firms for preliminary research. Through pre-research, the design of the questionnaire was aligned with the actual situation of the firms, ensuring that the respondents could accurately understand the various clauses in the questionnaire. In the formal research stage, we conducted research in Zhejiang, Shandong, Jiangsu, and other places, with sample firms from the manufacturing industry. Due to limitations of time and the number of personnel, we distributed a total of 300 questionnaires to firm managers. Ultimately, 269 questionnaires were collected, of which 27 were excluded due to incomplete measurement indicators or other reasons. Consequently, the final number of valid questionnaires was 242. Thus, the response rate of the questionnaire was 89.67%, and the effective rate was 80.67%.

The distribution of the effective sample is shown in Table 1.

3.2. Variable measurement

All items related to digital platform capability, environmental innovation quality, environmental uncertainty, and firms’ competitive advantage were measured using a five-point Likert scale. The respondents were asked to measure each item’s degree of conformity (between 1 and 5) with the actual management situation of their firms.

Table 1
Distribution of the samples.

Sample feature	Frequency (%)
Size	
249 or fewer employees	16.12
250–499 employees	40.50
500–999 employees	25.62
1000 or more employees	17.77
Property nature	
State-owned	20.25
Non-state-owned	79.75
Age	
5 years and below	4.13
5–10 years	26.86
11–15 years	34.71
Over 15 years	34.30
Industry	
High-tech industry	68.60
Non-high-tech industries	31.40

3.2.1. Digital platform capability

Drawing on Cenamor et al.’s (2019) measurement of digital platform capability, we adopted eight terms for its calculation, such as “Our firm’s platform easily accesses data from our partners’ information technology systems.” The Cronbach’s α of the scale was 0.738.

3.2.2. Environmental innovation quality

Previous research has lacked mature measurement scales for measuring the quality of environmental innovation. Based on the research performed by Lanjouw and Schankerman (2004), Pan et al. (2021), and Jiang and Bai (2022), we used four terms to measure the quality of firms’ environmental innovation, such as “Our firm’s green patents are often cited.” The Cronbach’s α of the scale was 0.771.

3.2.3. Environmental uncertainty

Drawing on Schilke’s (2014) approach, we employed five items to measure environmental uncertainty, such as “Environmental changes in our industry are unpredictable.” The Cronbach’s α of the scale was 0.812.

3.2.4. Competitive advantage

Drawing from the work of Chang (2011) and Singh et al. (2019), we employed six terms to measure competitive advantage, such as “Our firm’s profitability is better than that of competitors.” The Cronbach’s α of the scale was 0.824.

3.2.5. Control variables

We selected the age, size, property nature, and industry category of the firm as the control variables (Le and Lei, 2019; Wang et al., 2023b). Among them, firms with an establishment period of 5 years or below, 6–10 years, 11–15 years, and 16 years or more were assigned values of 1, 2, 3, and 4, respectively. The firm was assigned values of 1, 2, 3, and 4

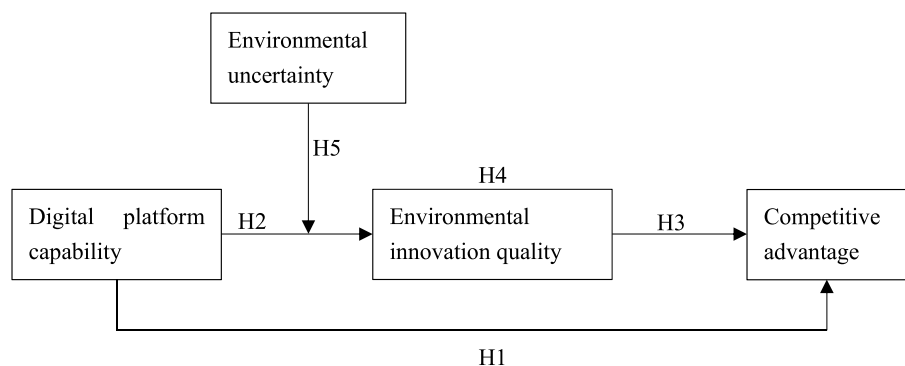


Fig. 1. Research model.

for fewer than 249 employees, 250–499 employees, 500–999 employees, and 1000 or more employees, respectively. State-owned firms were assigned a value of 1 and non-state-owned firms a value of 0. Firms in high-tech industries were assigned a value of 1, whereas those in non-high-tech industries were assigned a value of 0.

4. Results

4.1. Descriptive analysis

We first conducted correlation analysis tests on the variables, and the results were shown in Table 2.

Table 2 showed that the correlation coefficients between all variables ranged from 0.004 to 0.362, indicating that there was no serious multicollinearity problem. In addition, the data on mean and standard deviation demonstrated there to be certain differences in environmental uncertainty, environmental innovation quality, and competitive advantages among different firms, whereas the differences in digital platform capability between firms were found to be relatively small.

4.2. Hypothesis testing

- (1) Digital platform capability, environmental uncertainty, and firms' environmental innovation quality

We used SPSS 23.0 to establish a main effect regression analysis model. The results regarding the effects of the control variables, digital platform capability, and environmental uncertainty on the quality of the firms' environmental innovation are presented in Table 3. Taking the quality of environmental innovation as the dependent variable, Model 1 included only control variables. Model 2 added digital platform capability to Model 1, and Model 3 and Model 4 added environmental uncertainty and digital platform capability * environmental uncertainty, respectively, to Model 2.

The results of Model 1 reveal that industry categories ($\beta = 0.130$; $p < 0.05$) significantly and positively affected the quality of firms' environmental innovation. Specifically, firms in high-tech industries had higher-quality environmental innovation than their non-high-tech counterparts. Conversely, the impact of firms' size, age, and property rights on the quality of environmental innovation was not significant. The results of Model 2 reveal that digital platform capability ($\beta = 0.203$; $p < 0.01$) significantly and positively affected the quality of firms' environmental innovation; therefore, H2 was supported. The results of Models 3 and 4 suggest that digital platform capability * environmental uncertainty ($\beta = -0.182$; $p < 0.01$) significantly and negatively affected the quality of firms' environmental innovation. This indicates that environmental uncertainty played a negative moderating role in the impact of digital platform capability on the quality of firms' environmental innovation (Fig. 2). Therefore, H5 was supported.

The impact of digital platform capability and environmental innovation quality on the competitive advantage of firms is shown in Table 4. Taking competitive advantage as the dependent variable, Model 5 included only control variables, Model 6 added digital platform

capability to Model 5, Model 7 added environmental innovation quality to Model 5, and Model 8 covered the joint effect of digital platform capability and environmental innovation quality.

The results of Model 5 show that the nature of property rights ($\beta = -0.147$; $p < 0.05$) significantly and negatively affected firms' competitive advantage: Compared to non-state-owned firms, the level of competitive advantage of state-owned firms was relatively low. Meanwhile, the impact of firms' size, age, and industry category on competitive advantage was not significant. The results of Model 6 indicate that digital platform capability ($\beta = 0.228$; $p < 0.01$) significantly and positively affected the competitive advantage of firms, thus supporting H1. The results of Model 7 demonstrate that the quality of environmental innovation ($\beta = 0.353$; $p < 0.01$) significantly and positively affected the competitive advantage of firms, thus supporting H3. The results of Models 7 and 8 suggest that, when both digital platform capability and environmental innovation quality enter the model, the quality of environmental innovation ($\beta = 0.321$; $p < 0.01$) has a significant positive impact on the competitive advantage of firms, and digital platform capability ($\beta = 0.163$; $p < 0.01$) still significantly positively affects the competitive advantage of firms, but the impact coefficient decreases, indicating that the quality of environmental innovation plays a partial mediating role in digital platform capability's impact on the competitive advantage of firms. Therefore, H4 was supported.

5. Conclusion and discussion

5.1. Conclusion

This study took firms in the Chinese manufacturing industry as research samples to empirically test the impact of digital platform capability on firms' competitive advantage and its mediating path, as well as to examine the moderating effect of environmental uncertainty. The main conclusions are as follows.

First, digital platform capability has a positive effect on the competitive advantage of firms. The capabilities of digital platforms not only help firms integrate effective information from multiple parties (e.g., the government, consumers, suppliers, and markets) based on platform network systems, but also help firms streamline business processes, identify environmental changes, make and implement quick decisions, continuously optimize the allocation of internal and external resources, and enhance their ability to respond to dynamic environments and seize opportunities (Cenamor et al., 2019; Dubey et al., 2020). Thus, they provide a rich resource foundation and enable opportunity selection for the establishment of competitive advantages.

Second, the mechanism test revealed that the quality of environmental innovation plays a partial mediating role in the relationship between digital platform capability and firms' competitive advantage. On the one hand, digital platforms have the advantages of integrating key knowledge, collecting, acquiring, and sharing low-cost resources, and strengthening close cooperation between firms (Teece, 2018; Cenamor et al., 2019; Caputo et al., 2022). This weakens the inhibitory effect of the dual externalities of the environment and environmental

Table 2
Variable descriptive statistics and correlations.

Variables	M	S.D.	1	2	3	4	5	6	7	8
1. Size	2.45	0.964	1							
2. Age	2.99	0.883	0.331**	1						
3. Ownership	0.20	0.403	0.053	-0.065	1					
4. Industry category	0.69	0.465	0.076	-0.037	0.009	1				
5. Digital platform capability	3.999	0.470	0.036	0.071	-0.030	0.237**	1			
6. Environmental uncertainty	3.710	0.6434	-0.041	-0.117	0.100	0.055	0.344**	1		
7. Environmental innovation quality	3.611	0.789	0.076	0.027	-0.022	0.135*	0.225**	0.090	1	
8. Competitive advantage	3.877	0.688	0.079	0.064	-0.145*	0.065	0.238**	0.004	0.362**	1

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; N = 242.

Table 3
Digital platform capability, environmental uncertainty, and firms' environmental innovation quality.

Variables		Environmental innovation quality			
		Model 1	Model 2	Model 3	Model 4
Control variables	Firm size	0.065	0.066	0.067	0.031
	Firm age	0.008	-0.008	-0.005	0.006
	Ownership	-0.026	-0.020	-0.023	-0.016
	Industry category	0.130**	0.081	0.082	0.076
Independent variable	Digital platform capability		0.203***	0.194	0.141**
Moderator variable	Environmental uncertainty			0.024***	0.051
Interaction variable	Digital platform capability * Environmental uncertainty				-0.182***
	R ²	0.023	0.062	0.062	0.091
	ΔR ²	0.007	0.042	0.038	0.064
	F	1.410	3.108**	2.600**	3.360***

Note: *p < 0.1, **p < 0.05, ***p < 0.01; N = 242.

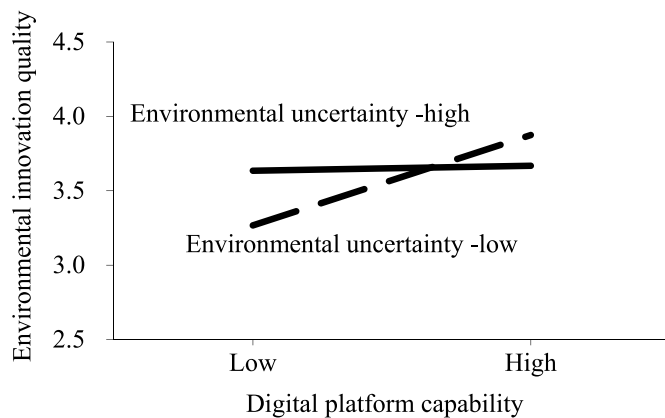


Fig. 2. Effect of digital platform capability on firms' environmental innovation quality under different levels of environmental uncertainty.

(2) Digital platform capability, environmental innovation quality, and firms' competitive advantage

innovation knowledge on firms' implementation of this strategy, and provides a substantial and innovative knowledge base for high-quality environmental innovation behavior, thus promoting such high-level behavior in firms. On the other hand, due to their substantive environmental benefits, high-quality environmental innovation activities have become an inherent and practical demand of all stakeholders (Horbach, 2008; Liao and Liu, 2021), bringing new markets and opportunities to firms that engage in them. Additionally, there are entry barriers to high-quality environmental innovation activities, which provide firms with sustained and stable competitive advantages (Zameer et al., 2022).

Third, environmental uncertainty weakens digital platform capability's positive impact on the quality of firms' environmental innovation. Environmental uncertainty describes the volatility and unpredictability of an organization's external environment (Pagell and

Krause, 2004). The increase in environmental uncertainty can lead to growing difficulties in firms' ability to obtain effective external information, increases in market risk (Verdu et al., 2012), and a weakening of digital platforms' capability to identify and respond to market demand and opportunities. In this context, the difficulty of processing information increases for firms' decision-makers. To avoid investment failure, firms reduce their investment in activities with highly-uncertain returns, such as high-quality environmental innovation. This weakens the promoting effect of digital platform capability on the quality of firms' environmental innovation.

5.2. Theoretical implications

First, this study found that digital platform capability effectively supports manufacturing firms in shaping competitive advantages, which provides an empirical basis for firms to seize the opportunities created by digital transformation. Second, unlike previous studies, this study analyzed the path through which digital platform capability plays a role in enhancing competitive advantage from the perspective of environmental innovation quality. This offers a new perspective for the theoretical community to understand how digital platforms can help enhance a firm's competitive advantage. Third, environmental uncertainty was selected as the moderating variable. Our analysis of the changes in the impact of digital platform capability on the quality of firms' environmental innovation can serve as a reference for firms to improve the quality of their environmental innovation based on external environmental changes. Additionally, it enhances the explanatory power of the impact of digital platform capability on the quality of firms' environmental innovation.

5.3. Managerial implications

The conclusions drawn from this study have the following implications for governments and firms. First, this article confirms the driving effect of digital platform capability on the competitive advantage of

Table 4
Digital platform capability, environmental innovation quality, and firms' competitive advantage.

Variables		Competitive advantage			
		Model 5	Model 6	Model 7	Model 8
Control variables	Firm size	0.071	0.073	0.049	0.052
	Firm age	.033	0.015	0.031	0.018
	Ownership	-0.147**	-0.141**	-0.138**	-0.134**
	Industry category	0.062	0.007	0.016	-0.019
Independent variable	Digital platform capability		0.228***		0.163***
Mediator variable	Environmental innovation quality			0.353***	0.321***
	R ²	0.033	0.082	0.155	0.179
	ΔR ²	0.017	0.062	0.137	0.158
	F	2.031*	4.213***	8.632***	8.514***

Note: *p < 0.1, **p < 0.05, ***p < 0.01; N = 242.

firms. Therefore, on the one hand, the government should introduce corresponding preferential policies, such as tax credits for digital platform construction costs, to guide firms in the manufacturing industry to increase investment in informationization construction. Moreover, the government or industry associations should form a digital platform alliance, and report the excellent experience of the digital platform “leader” firms within the alliance to learn from and grow with each other. Additionally, the government can fund (regional partner) provinces to establish digital platform grassroots facilities to reduce SMEs’ difficulties in improving their digital platform capabilities due to financial and resource deficiencies. On the other hand, corporate decision makers, realizing the huge potential of digital platform capability in building a new set of core competitive advantages, should tilt their resources to increase investment in digital platform construction and capability enhancement. Second, firms should fully utilize the advantages of digital platforms in information collection, sharing, and processing, accurately identify the environmental needs of stakeholders, expand their customer resources, acquire the knowledge or resources required for environmental innovation, and achieve the optimal allocation of resources to enhance their level of environmental innovation. Third, while recognizing the role of digital platform capability in improving the quality of environmental innovation, firms should also closely monitor changes in the external environment, especially uncertainty. Based on continuous environmental scanning, firms can analyze and use environmental information to reduce the adverse effects of environmental uncertainty.

5.4. Limitations and directions for future research

The following limitations should be acknowledged. First, the relationship between digital platform capability and firms’ competitive advantage is inevitably influenced by external and internal factors. We only selected environmental uncertainty as the moderating variable. Therefore, future research can incorporate more moderating variables so as to explore their joint effects. Second, we selected firms in the manufacturing industry as the research sample, but did not cover all industries. Consequently, the results may not be generalizable to all firms. Future research should expand the sample and compare the differences in results between different industries. Third, from the perspective of environmental innovation, this study mainly analyzed the internal path of the impact of digital platform capability on firms’ competitive advantage; however, numerous other paths could be investigated. Future research could explore more internal pathways, as well as their importance.

Compliance with ethical standards

All authors declare no interest of conflict.

CRedit authorship contribution statement

Zhongju Liao: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Jie Chen:** Formal analysis, Writing – original draft, Writing – review & editing. **Xueli Chen:** Formal analysis, Writing – review & editing. **Malin Song:** Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing.

Data availability

Data will be made available on request.

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