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The Effect of Digital Transformation on the Speed of Enterprise Internationalization: A Dual Innovation Perspective

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Abstract:

In the context of intensifying deglobalization and the reshaping of the global competitive landscape by digital technologies, digital transformation enables firms to overcome traditional constraints on internationalization and reconfigure their paths of overseas expansion. However, although prior research has accumulated substantial evidence on the relationship between digitalization and internationalization, it still lacks a systematic explanation of whether and how digital transformation accelerates the speed of enterprise internationalization through firms' innovation activities, and insufficient attention has been paid to the boundary conditions under which this relationship varies across firms and environments. To address this gap, this study aims to explain how and under what conditions digital transformation increases the speed of enterprise internationalization by examining the parallel mediating roles of exploitative innovation and exploratory innovation, as well as the contingent moderating role of policy uncertainty. Drawing on the resource-based perspective, transaction cost theory, and dynamic capability theory, and using a sample of A-share listed firms from 2008 to 2022, the panel regression method is employed to test the proposed framework. The results indicate that digital transformation significantly increases the speed of enterprise internationalization and that both exploitative and exploratory innovation play significant mediating roles. Furthermore, policy uncertainty positively moderates both the effects of digital transformation on the two innovation modes and the effects of the two innovation modes on internationalization speed.

Keywords: Digital Transformation; Speed of Internationalization; Ambidextrous Innovation; Policy Uncertainty

1 Introduction

International business activities have increasingly been exposed to techno-geopolitical uncertainty, trade protectionism, and global disorder, which intensify institutional

frictions and transaction costs in cross-border operations (Luo & Van Assche, 2023). Luo (2024) further emphasizes that global disorder has reshaped the theoretical and strategic conditions of international business. Meanwhile, digital transformation, driven by big data, artificial intelligence, cloud computing, and digital platforms, has reshaped firms' value creation models, organizational coordination logics, and international market connectivity (Strange et al. 2022). Schmeisser et al. (2026) similarly highlight digital transformation as a central force reshaping international business. Digitalization also changes business models and value capture (Caputo et al., 2021). It further affects firms' internationalization processes and cross-border operating capabilities (Dethine et al., 2020). Digital platforms and ecosystems provide new conditions for cross-border resource integration, knowledge acquisition, and market connectivity (Nambisan et al., 2019). Digitalization also modifies cross-border governance and internal resource allocation, thereby affecting the path and pace of international expansion (Banalieva & Dhanaraj, 2019). Therefore, how firms use digital transformation to accelerate internationalization has become an important issue in international business and strategic management.

Existing studies have accumulated evidence on the relationship between digital transformation and enterprise internationalization. Digitalization can improve firms' internationalization conditions by enhancing cross-border connectivity, resource integration efficiency, and overseas knowledge acquisition. Yan et al. (2023) show that firm digitalization positively affects the speed of internationalization. Dethine et al. (2020) further indicate that digitalization improves export-management resources and capabilities. From a broader international business perspective, digitalization also reshapes cross-border governance and internal resource allocation (Banalieva & Dhanaraj, 2019). However, digitalization does not automatically translate into internationalization performance. Strange et al. (2022) argue that the effects of digitalization on traditional firms' international strategies require further clarification. Denicolai et al. (2021) show that the benefits of digitalization depend on organizational capabilities, strategic fit, and external conditions. Therefore, the mechanisms and

boundary contexts through which digital transformation affects internationalization speed remain insufficiently explained.

To explain why the effect of digitalization on internationalization varies, recent studies have shifted from direct outcome relationships to more specific transmission mechanisms. Digital platforms and ecosystems help firms acquire cross-border knowledge, build relationships, and create value (Nambisan et al., 2019). Internationalization and digital strategies are also increasingly embedded in each other during international operations (Meyer et al., 2023). From a global value-chain perspective, digitalization changes power relations and resource-dependence structures (Oliveira et al., 2021). From an internalization-theory perspective, digitalization reshapes cross-border governance and internal resource allocation (Banalieva & Dhanaraj, 2019). Studies on emerging-market SMEs further show that digitalization promotes outward foreign direct investment through dynamic capabilities (Qiao et al., 2024). However, these studies remain mainly focused on efficiency, connectivity, governance, and cost, and they have not sufficiently explained how digital transformation affects internationalization speed through firm innovation activities. Ambidextrous innovation provides a useful mechanism. Exploitative innovation emphasizes the improvement and reuse of existing knowledge, technologies, and processes, whereas exploratory innovation emphasizes the development of new knowledge, technologies, products, and market opportunities (Lisboa et al., 2011). Exploitative and exploratory capabilities also affect international market performance and internationalization speed (Lin & Si, 2019). Digital transformation reshapes firms' search, recombination, and innovation processes (Lanzolla et al., 2021). Firms also develop evolving innovation portfolios as digitalization advances (Zhang et al., 2023). However, the innovation effect of digital technology depends on how firms embed it into organizational and R&D activities (Usai et al., 2021). Therefore, ambidextrous innovation is a suitable entry point for explaining how digital transformation affects internationalization speed.

Internationalization speed is embedded in external institutional environments and policy expectations (Sun et al., 2021). It involves the timing of foreign market entry, the breadth of host-country expansion, and the depth of overseas operations over time (Chetty et al., 2014). Its formation and consequences are shaped by knowledge accumulation, learning processes, and environmental conditions (Hilmersson & Johanson, 2016). Policy uncertainty affects firms' international expansion by altering their judgments about risk, returns, and resource commitments (Tang, 2023). It may suppress investment and strengthen wait-and-see behaviour (Gulen & Ion, 2016). It may also make firms more cautious in R&D adjustment (Bloom, 2007). However, policy uncertainty does not only have an inhibitory effect. It can influence corporate innovation decisions (He et al., 2020). It can also promote innovation digitalization through ambidextrous innovation (Yang et al., 2022). Therefore, ignoring policy uncertainty would make it difficult to explain why the relationships among digital transformation, ambidextrous innovation, and internationalization speed vary across firms.

To integrate the mechanisms and boundary conditions discussed above, this study develops a framework linking digital transformation, ambidextrous innovation, policy uncertainty, and internationalization speed. The resource-based perspective explains why digital transformation can become a strategic resource for firms (Barney, 1991). Dynamic capability theory explains how firms transform digital resources into exploitative and exploratory innovation capabilities (Teece et al., 1997). Internalization theory explains why firms use digitalization to restructure resource allocation and organizational boundaries in cross-border operations (Buckley & Casson, 1976). Transaction cost theory explains how digital technologies reduce information search, communication, coordination, and contract enforcement costs in international expansion (Coase, 1937). However, prior studies have not sufficiently explained how digital transformation accelerates internationalization speed through parallel innovation mechanisms or how policy uncertainty conditions this process. This study therefore makes three contributions. First, it reveals the parallel mediating roles of exploitative

and exploratory innovation. Second, it identifies policy uncertainty as a boundary condition of the innovation-based transmission path. Third, it places digital transformation, innovation capability, and internationalization speed within a unified theoretical framework. Empirically, this study tests a framework comprising two parallel mediation paths and moderation at both stages. The results show that digital transformation accelerates internationalization, both innovation-based indirect paths are significant, and policy uncertainty strengthens the conversion of digital transformation into innovation and of innovation into internationalization speed.

2 Conceptual Model and Hypotheses

In the digital era, digital transformation can be considered an important starting point for firms to develop strategic resources, restructure organizational capabilities, and optimize cross-border governance. The resource-based perspective argues that competitive advantage is derived primarily from the scarce resources that firms possess and effectively allocate (Barney, 1991). Within this context, data, algorithms, platforms, and digital organizational capabilities constitute a new resource base that is increasingly embedded within the internationalization strategies of firms (Meyer et al., 2023). This theory further suggests that firms can sustain a competitive advantage in highly dynamic international environments only by continuously integrating, reconfiguring, and renewing internal and external resources (Teece et al., 1997) and that the organizational restructuring and capability upgrading provided by digitalization essentially reflect the enhancement in the dynamic capabilities of firms (Nambisan et al., 2019). Moreover, when external markets are characterized by incomplete information, knowledge leakage risks, and coordination friction, firms typically substitute market transactions with internal organizational coordination (Banalieva & Dhanaraj, 2019). The search, negotiation, monitoring, and enforcement costs involved in cross-border operations shape the path and pace of international expansion in firms, while digital technologies significantly reshape these cost structures (Jean et al., 2010). Based on the above theoretical arguments and prior evidence that the effects of digitalization on internationalization and firm outcomes are contingent rather than

automatic, this study argues that digital transformation does not automatically generate an advantage in terms of the internationalization speed (Strange et al. 2022; Bhandari et al., 2023; Ciulli et al., 2023). Rather, digital transformation first reshapes the capability positions of firms through exploitative and exploratory innovation, which is then translated into more rapid internationalization through innovation-based capability conversion. Moreover, policy uncertainty affects the efficiency with which resources are converted into capabilities and capabilities into internationalization speed (Jiang & Wang, 2024; Bhandari et al., 2023).

2.1 Direct Influence of Enterprise Digital Transformation on the Speed of Internationalization

Digital transformation challenges the traditional incremental logic of internationalization process theory. The Uppsala model (Johanson and Vahlne, 1977) posits that firms internationalize gradually through sequential commitment due to limited market knowledge and uncertainty. However, digital technologies fundamentally alter this dynamic by enabling virtual knowledge acquisition, platform-mediated cross-border interactions, and reduced psychic distance (Bhatti et al., 2022). Consequently, digital transformation enables firms to accelerate their internationalization pace beyond what traditional stage models would predict. As a core manifestation of the pace of international expansion among firms, the speed of internationalization fundamentally depends on whether firms possess the ability to rapidly identify overseas opportunities, integrate cross-border resources, and achieve organizational adaptation (Chetty et al., 2014). From a resource-based perspective, digital transformation provides firms with a new strategic resource base through the accumulation of data, algorithms, and platform capabilities (Barney, 1991). From a dynamic capability theory perspective, digital technologies enable firms to perceive changes in international markets more clearly and to allocate resources and adjust strategies more rapidly, thereby shortening the internationalization learning curve and increasing the level of cross-border adaptability (Nambisan et al., 2019). Moreover, internalization theory and transaction cost theory suggest that digitalization alters the efficiency conditions of cross-border governance and organizational boundaries in

firms. On the one hand, firms can rely on digital technologies to strengthen global value chain coordination and increase the internal control and resource allocation efficiency (Banalieva & Dhanaraj, 2019). On the other hand, digital technologies can reduce the information search, coordination and communication, and monitoring and enforcement costs in cross-border transactions, thereby accelerating the pace at which firms enter and expand in overseas markets (Jean et al., 2010). Studies have also revealed that digitalization can significantly promote firms' international expansion and outward foreign investment and that its key mechanism lies in enhancing the dynamic and cross-border resource allocation capabilities of firms (Qiao et al., 2024). Therefore, digital transformation should, overall, be manifested as an increase in the speed of enterprise internationalization. Accordingly, the following hypothesis is proposed:

Hypothesis H1: Digital transformation positively promotes the speed of enterprise internationalization.

2.2 Mediating Role of Exploitative Innovation

After establishing the direct link between digital transformation and internationalization speed, this study further considers the internal mechanism through which this effect is realized. Within the framework of this study, exploitative innovation serves as an important internal transmission mechanism through which digital transformation affects the internationalization speed. Exploitative innovation emphasizes the optimization, recombination, and reuse of existing knowledge, existing technologies, and established processes, with its core lying in improving existing products and operational systems to increase efficiency and stability levels (Lisboa et al., 2011). Digital transformation can increase the efficiency of firms in using existing resources through data integration, process visualization, and algorithm optimization and can drive continuous improvement along familiar technological trajectories (Lanzolla et al., 2021). From a resource-based perspective, the data governance, knowledge search, and process reconfiguration abilities established through digitalization are themselves important resources that are difficult for competitors to imitate (Barney, 1991). From a transaction cost theory perspective, exploitative innovation in turn helps firms reduce coordination costs, repetitive trial-and-error costs,

and communication costs in cross-border operations, thereby strengthening their efficiency advantage in international markets (Jean et al., 2010). Such efficiency improvements are reflected not only in the optimization of existing product quality and services but also in enhanced supply chain responsiveness, greater stability in cross-border operations, and improved ability to replicate in overseas markets, all of which ultimately help firms advance their internationalization process more rapidly. Therefore, the effect of digital transformation on the internationalization speed should be partially realized through the mechanism of exploitative innovation. Accordingly, the following hypothesis is proposed:

Hypothesis H2: Exploitative innovation plays a positive mediating role in shaping the relationship between digital transformation and the speed of enterprise internationalization.

2.3 Mediating Role of Exploratory Innovation

Unlike exploitative innovation, exploratory innovation emphasizes the development of new knowledge, new technologies, and new market opportunities, with its core lying in overcoming existing knowledge boundaries and generating new products, services, and modes of competition (Lin & Si, 2019). Digital transformation not only alters firms' resource structures but also enhances exploratory innovation by expanding the scope of knowledge search, improving cross-organizational collaboration abilities, and reshaping innovation processes (Lanzolla et al., 2021). From a dynamic capability theory perspective, digitalization enables firms to sense opportunities, seize opportunities, and reconfigure resources more easily in complex environments and therefore is more likely to promote the experimentation, learning, and recombination capabilities needed for exploratory innovation (Teece et al., 1997). From an internalization-theory perspective, firms also reshape their knowledge boundaries and innovation boundaries by connecting to external knowledge sources through digital platforms and digital networks (Banalieva & Dhanaraj, 2019). Existing studies have reported that digital transformation induces changes in the innovation portfolios of

firms and that exploratory innovation provides important support for the successful implementation of digital transformation (Zhang et al., 2023). Specifically, exploratory innovation can help firms develop new products, services, and business models that better match overseas demands, thereby increasing their differentiated competitiveness and expansion speed in international markets (Lin & Si, 2019). Therefore, the effect of digital transformation on the speed of internationalization should also be partially realized through the mechanism of exploratory innovation. Accordingly, the following hypothesis is proposed:

Hypothesis H3: Exploratory innovation plays a positive mediating role in shaping the relationship between digital transformation and the speed of enterprise internationalization.

2.4 Moderating Role of Policy Uncertainty

Whether digital transformation can be successfully translated into innovation capabilities and in turn increase the speed of internationalization also depends on the external institutional environment. Policy uncertainty indicates that firms face greater rule volatility, expectation deviations, and decision-making risks, which affect their judgements with respect to investment, innovation, and the pace of international expansion (Gulen & Ion, 2016). On the one hand, uncertainty may suppress investment and reinforce wait-and-see behaviour (Bloom, 2007). On the other hand, in complex and volatile institutional environments, firms may become more reliant on digital technologies to improve their information-processing capabilities, increase their flexibility, and seek new growth paths (He et al., 2020). From a dynamic capability theory perspective, the greater the level of policy uncertainty is, the more firms must respond to environmental change through rapid sensing, resource reconfiguration, and organizational adaptation, and digitalization constitutes an important foundation for the development of such capabilities (Teece et al., 1997). From transaction cost and internalization theory perspectives, the more unstable the external environment is, the stronger the incentives for firms to rely on digital means to reduce information asymmetry and cross-border governance friction and to buffer institutional risk through strengthened internal coordination (Banalieva & Dhanaraj, 2019). Existing studies have

revealed that in uncertain environments, digitalization and ambidextrous innovation often exhibit a stronger coupling relationship, and policy uncertainty reinforces the empowering effect of digital technologies on innovation digitalization and the expansion of knowledge boundaries (Yang et al., 2022). Moreover, instability in the institutional environment alters the mechanisms through which the international expansion and overseas entry decisions of firms are established (Tang, 2023). Therefore, policy uncertainty may not only amplify the driving effects of digital transformation on exploitative innovation and exploratory innovation but also enhance the extent to which these two types of innovation are transformed into advantages in terms of the internationalization speed. Accordingly, the following hypotheses are proposed:

Hypothesis H4a: The greater the level of policy uncertainty is, the stronger the promoting effect of digital transformation on exploitative innovation.

Hypothesis H4b: The greater the level of policy uncertainty is, the more notable the promoting effect of exploitative innovation on the speed of enterprise internationalization.

Hypothesis H4c: The greater the level of policy uncertainty is, the stronger the promoting effect of digital transformation on exploratory innovation.

Hypothesis H4d: The greater the level of policy uncertainty is, the more notable the promoting effect of exploratory innovation on the enterprise-internationalization speed.

On the basis of the above hypotheses, Figure 1 summarizes the proposed transmission logic. Digital transformation is expected to directly promote the speed of internationalization and indirectly affect it through two parallel innovation paths, namely exploitative innovation and exploratory innovation. Policy uncertainty further moderates the conversion from digital transformation to ambidextrous innovation and from ambidextrous innovation to internationalization speed.

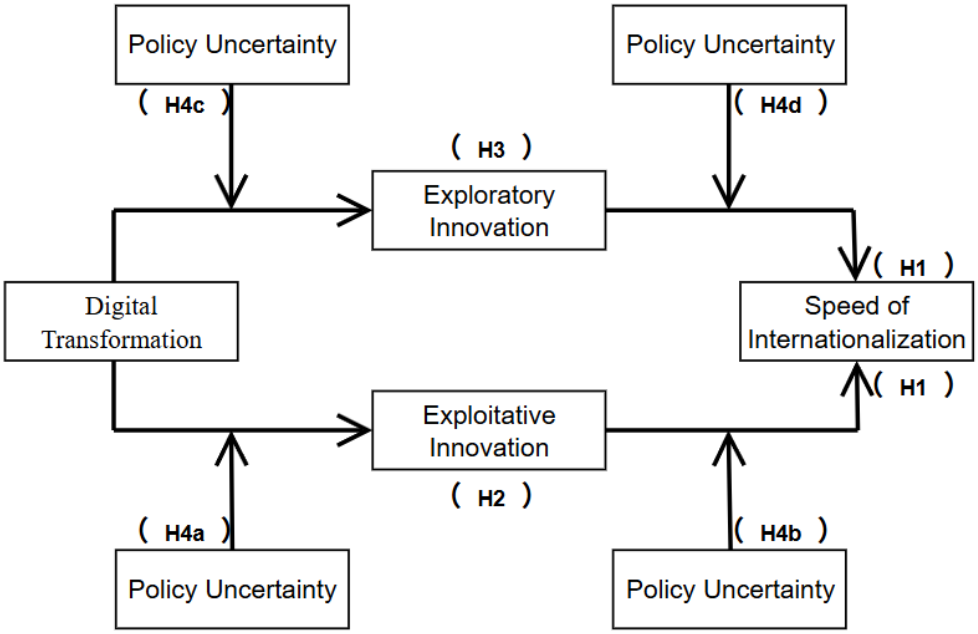


Figure 1 Analysis of how enterprise digital transformation influences the pace of internationalization

3 Methods

3.1 Sample and Data Collection

In this study, Chinese A-share listed companies from 2008 to 2022 are adopted as the research sample to examine the mechanism through which digital transformation affects the enterprise-internationalization speed via ambidextrous innovation. Since this study focuses on listed companies with internationalization activities, the sample selection process must simultaneously satisfy multidimensional data requirements, including the measurement of the internationalization speed, the identification of digitalization-related text and innovation output, and the characterization of policy uncertainty.

In terms of sample screening, annual reports and related financial data of A-share listed companies from 2008 to 2022 were first collected. Next, following common sample-screening practices in studies using Chinese listed firms, samples from financial and insurance industries, firms under ST or *ST status conditions during the sample period, and firms with severe missing values for key variables were excluded (Zhao, 2021). Thereafter, at the level of measuring the internationalization speed, only firms for which

the year of first outward foreign direct investment, the number of overseas subsidiaries, and the host countries of overseas investment could be identified were retained. Finally, annual report texts, patent application data, financial indicators, corporate governance variables, and firm-level policy uncertainty indicators were matched to establish the final unbalanced panel dataset for regression analysis. According to the descriptive statistics, the final baseline sample comprises 1,405 listed firms and 9,306 firm-year observations. The dataset is an unbalanced firm-year panel that integrates annual report texts, patent application records, financial and governance indicators, overseas investment information, and firm-level policy uncertainty measures

The data used in this study are derived mainly from the following sources. Annual reports of the listed companies are used primarily to establish a digital transformation indicator and a firm-level policy uncertainty indicator. Corporate financial data, corporate governance data, overseas investment data, and patent application data are obtained mainly from the China Stock Market and Accounting Research (CSMAR) database. Text analysis is conducted using Python programs for annual report collection, cleaning, segmentation, and word-frequency statistics. Empirical regression analysis is performed using Stata 17.0.

3.2 Variable Definitions

(1) Dependent Variable: Speed of Internationalization (Speed).

The speed of internationalization is chosen as the dependent variable. Drawing on the classical measurement approach for the internationalization speed, the internationalization process of firms is divided into two dimensions, namely, breadth and depth (Hilmersson & Johanson, 2016). Furthermore, by incorporating the dynamic measurement approach applied in studies on the internationalization of Chinese firms, an indicator of the enterprise-internationalization speed is established (Xie, 2023). Specifically, the depth of internationalization is measured by the number of overseas subsidiaries of a firm, while the breadth of internationalization is measured by the number of host countries in which the firm has invested. The time interval between the year in which the firm first implemented outward foreign direct investment and the reporting year is adopted as the internationalization duration, and the ratio of the degree

of internationalization to the duration of internationalization is used as the internationalization speed of the firm. The larger the value of this indicator is, the faster the firm expands into overseas markets and establishes cross-border operations within a given period.

(2) Core Explanatory Variable: Digital Transformation

In this study, digital transformation is adopted as the core independent variable. Following the annual report text analysis approach, a digital transformation index is developed for firms (Zhao, 2021). The specific procedure is as follows: first, annual reports of listed companies from 2008 to 2022 are collected, and core textual sections such as Management Discussion and Analysis, which can reflect the operating strategies and technology application of firms, are extracted. Second, Chinese word segmentation is conducted and word-frequency statistics are obtained using Python and the Jieba segmentation tool, respectively. Third, on the basis of existing studies, a dictionary of digitalization-related keywords is compiled (Supplementary Table S1) that covers multiple dimensions, such as artificial intelligence, big data, cloud computing, blockchain, information technology, and the Internet of Things (Zhao, 2021). Fourth, the frequency of relevant keywords is determined at the firm-year level, and the word-frequency data are standardized and transformed by calculating the natural logarithm after adding one, thereby obtaining the overall index of enterprise digital transformation. The larger the value of this indicator is, the greater the degree of digital transformation reflected in the annual report of that firm. The Digital variable is constructed as the natural logarithm of one plus the total frequency of digitalization-related keywords identified in the MD&A section of the annual report. This logarithmic transformation reduces the skewness of the keyword-frequency distribution. In the final sample, Digital has a mean of 2.387 and a standard deviation of 1.220.

(3) Mediating Variables: In this study, ambidextrous innovation is divided into two dimensions, namely, exploratory innovation and exploitative innovation. Drawing on the study of Zhong et al. (2014), exploratory innovation (Invention) is measured as the natural logarithm of the number of invention patent applications filed by a firm in the

current year plus one, while exploitative innovation (Design) is measured as the natural logarithm of the sum of utility model patent applications and design patent applications filed by a firm in the current year plus one. This distinction is made because invention patents can better reflect the breakthrough exploration of new knowledge and new technologies in firms, whereas utility models and design patents place greater emphasis on the improvement, optimization, and extension of existing technologies and products and are therefore more consistent with the characteristics of exploitative innovation (Zhong et al., 2014; Benner & Tushman, 2003).

(4) Moderating Variable: Policy uncertainty serves as the key moderating variable in this study. Following the annual report text-based approach, in this study, a firm-level economic policy uncertainty indicator is developed on the basis of corporate annual reports (Nie et al., 2020). Specifically, annual report texts of the listed companies are first collected, and core sections such as Management Discussion and Analysis or Board of Directors' Reports are extracted. Second, the texts are cleaned, segmented into sentences, and tokenized. Third, sentence identification and keyword matching are conducted on the basis of a preestablished dictionary of policy-related terms and uncertainty-related terms (Nie et al., 2020). Finally, the total number of uncertainty-related words in sentences identified as economic policy uncertainty-related sentences is divided by the total number of words in the cleaned text to obtain the firm-level policy uncertainty index. The higher the value of this indicator is, the greater the degree to which the firm expresses uncertainty with respect to the external policy environment in its annual report.

(5) Control Variables: To control for the potential effects of firm-level characteristics on the internationalization speed, the firm size (Size), firm age (Age), return on assets (ROAB), and CEO-chair duality (Dual) are included as control variables in the baseline model of this study. The firm size is measured as the natural logarithm of the total assets, reflecting the resource endowment and organizational scale of firms. The firm age is measured as the logarithmic form of the number of years since listing, capturing the accumulation of experience and organizational maturity of firms. The return on assets is measured as the ratio of the net profit to the total assets to control for differences in

firm profitability. CEO-chair duality is employed as a dummy variable that takes a value of 1 when the chairperson of the board and general manager positions are held by the same person and 0 otherwise. This indicator is adopted to control for the influence of the corporate governance structure on internationalization decisions.

3.3 Estimation Approach

The empirical analyses are conducted using Stata 17.0. The reported test statistics and estimation methods follow the specifications stated in the corresponding table notes. The baseline, mediation, and moderation results report z-statistics, while the robustness analyses employ random-effects GLS and 2SLS specifications.

3.4 Model

To examine the direct influence of digital transformation on the enterprise-internationalization speed, the following baseline regression model is first established with reference to empirical studies on digital transformation and firm internationalization using panel regression designs (Yan et al., 2023; Jiang & Wang, 2024):

$$Speed_t = \beta_0 + \beta_1 Digital_t + \beta_i Controls_t + \xi \quad (1)$$

where $Speed_t$ is the dependent variable, which represents the enterprise-internationalization speed during period t; $Digital_t$ is the core independent variable, which represents the level of enterprise digital transformation during period t; $Controls_t$ denotes the control variables during period t; and ξ is the random error term.

To examine the mediating effect of ambidextrous innovation, the following mediation models are subsequently developed. For exploratory innovation, the models can be expressed as follows:

$$Inwention_t = \beta_0 + \beta_1 Digital_t + \beta_i Controls_t + \xi \quad (2)$$

$$Speed_t = \beta_0 + \beta_1 Invention_t + \beta_2 Digital_t + \beta_i Controls_t + \xi \quad (3)$$

For exploitative innovation, the models can be formulated as follows:

$$Design_t = \beta_0 + \beta_1 Digital_t + \beta_i Controls_t + \xi \quad (4)$$

$$Speed_t = \beta_0 + \beta_1 Design_t + \beta_2 Digital_t + \beta_i Controls_t + \xi \quad (5)$$

If digital transformation significantly affects the mediating variable and if after the mediating variable is added, the coefficient of the mediating variable remains significant while the absolute value of the coefficient of digital transformation decreases, ambidextrous innovation is then considered to play a mediating role in the process through which digital transformation affects the internationalization speed.

To examine the moderating effect of policy uncertainty, in this study, moderation models are established to investigate the influence of policy uncertainty at two stages, namely, digital transformation → ambidextrous innovation and ambidextrous innovation → speed of internationalization. The specific forms are as follows:

$$Invention_t = \beta_0 + \beta_1 Digital_t + \beta_2 Fepu_t + \beta_3 Digital_t \times Fepu_t + \beta_i Controls_t + \xi \quad (6)$$

$$Design_t = \beta_0 + \beta_1 Digital_t + \beta_2 Fepu_t + \beta_3 Digital_t \times Fepu_t + \beta_i Controls_t + \xi \quad (7)$$

$$Speed_t = \beta_0 + \beta_1 Invention_t + \beta_2 Fepu_t + \beta_3 Invention_t \times Fepu_t + \beta_i Controls_t + \xi \quad (8)$$

$$Speed_t = \beta_0 + \beta_1 Design_t + \beta_2 Fepu_t + \beta_3 Design_t \times Fepu_t + \beta_i Controls_t + \xi \quad (9)$$

where $Fepu_t$ denotes firm-level policy uncertainty. If the coefficient of the interaction term is significant, this indicates that policy uncertainty exerts a significant moderating effect on the transmission path through which digital transformation influences the internationalization speed via ambidextrous innovation.

4 Results and Analysis

4.1 Descriptive Statistics and Correlation Analysis

Table 1 reports the descriptive statistics and correlations of the main variables. Digital has a mean of 2.387 and a standard deviation of 1.220, indicating substantial variation in the level of digital transformation across the sampled firms. Digital is positively

correlated with Speed, Design, and Invention, with correlation coefficients of 0.0640, 0.0787, and 0.1377, respectively, providing preliminary support for the proposed digital transformation – innovation – internationalization mechanism. The correlation between Design and Invention is 0.3969, suggesting that the two innovation modes are related but remain distinguishable. This pattern is consistent with prior studies emphasizing that digital transformation reshapes knowledge creation, process optimization, and business model innovation while requiring differentiated organizational absorption and conversion processes (Chen et al., 2024; Bresciani et al., 2021). Fepu is weakly negatively correlated with Digital, with a coefficient of −0.0674, consistent with the view that policy uncertainty may constrain firms' investment and innovation expectations (Lou et al., 2022). The largest absolute pairwise correlation, excluding the diagonal, is 0.3969, indicating no serious pairwise correlation problem.

4.2 Baseline Regression Results

The baseline regression is conducted to test whether digital transformation directly promotes the speed of enterprise internationalization, corresponding to Hypothesis H1. Specifically, the baseline model regresses internationalization speed on digital transformation while controlling for firm size, firm age, profitability, and governance structure. As shown in column (1) of Table 2, digital transformation has a positive and statistically significant effect on enterprise internationalization speed. The coefficient is 0.043, with a z-statistic of 3.63, and is significant at the 1% level. Therefore, H1 is supported, indicating that firms with higher levels of digital transformation tend to internationalize more rapidly. This result is consistent with the view that digital strategy and internationalization strategy are increasingly embedded in each other (Meyer et al., 2023) and with evidence that strategic agility contributes to faster internationalization (Demir et al., 2021).

4.3 Bootstrap Mediation Test Results

Following Preacher and Hayes (2008), bootstrap tests are used to assess the two indirect effects. The indirect effect through exploitative innovation is 0.0046, with a bias-corrected 95% confidence interval of [0.0024, 0.0071]. The indirect effect through exploratory innovation is 0.0087, with a 95% confidence interval of [0.0056, 0.0130].

Because neither confidence interval includes zero, both exploitative and exploratory innovation have significant mediating effects, supporting H2 and H3. The estimated indirect effect through exploratory innovation exceeds that through exploitative innovation by 0.0042. However, the difference is not jointly tested, and therefore the exploratory pathway can only be described as numerically larger rather than statistically stronger.

Overall, the baseline result establishes the direct empirical foundation for the subsequent mechanism tests.

4.4 Mediation Effect Tests

Table 2 shows that both exploitative and exploratory innovation partially mediate the relationship between digital transformation and internationalization speed. Along the exploitative path, Digital significantly increases Design, and Design remains positive and significant after being added to the Speed equation. This is consistent with the view that digital transformation improves process visualization, knowledge recombination, and business optimization capabilities (Bresciani et al., 2021). Along the exploratory path, Digital has a stronger effect on Invention, and Invention also remains positive and significant in the Speed equation. The bootstrap tests further confirm that both indirect effects are significant. The estimated indirect effect through exploratory innovation is 0.0087, and exploitative innovation is 0.0046. These results indicate that digital transformation accelerates internationalization by converting digital capabilities into innovation capabilities, especially exploratory innovation (Liu et al., 2023; Chen et al., 2024).

4.5 Moderation Effect Tests

Table 3 shows that policy uncertainty positively moderates both stages of the two innovation-based transmission paths. The coefficient of the Digital x Fepu interaction is 0.058 in the Design model and 0.034 in the Invention model; both are significant at the 1% level. These results indicate that policy uncertainty strengthens the positive effects of digital transformation on both exploitative and exploratory innovation. The coefficient of Design x Fepu is 0.021, while that of Invention x Fepu is 0.018; both are also significant at the 1% level. Thus, policy uncertainty strengthens the conversion of

both innovation modes into internationalization speed, supporting H4a, H4b, H4c, and H4d. Overall, policy uncertainty operates as a pressure-transmission condition that strengthens innovation-based internationalization rather than merely suppressing firm action (Lou et al., 2022; Benischke et al., 2022; Meyer et al., 2023; Tang, 2023).

Table 3 shows that policy uncertainty strengthens both stages of the innovation-based transmission mechanism. The interaction terms between Digital and Fepu are positive and significant for both Design and Invention, indicating that policy uncertainty reinforces the effect of digital transformation on ambidextrous innovation. The interaction terms between Design and Fepu and between Invention and Fepu are also positive and significant, suggesting that policy uncertainty enhances the conversion of innovation into internationalization speed. A falsification test using subsidiary survival rates yields an insignificant moderation effect (beta = -0.003, p = 0.684), reducing the concern that the result reflects non-strategic risk-taking. Overall, policy uncertainty operates as a pressure-transmission condition that strengthens innovation-based internationalization rather than merely suppressing firm action (Lou et al., 2022; Benischke et al., 2022; Meyer et al., 2023; Tang, 2023).

5 Further Analysis and Tests

5.1 Consistency and Robustness Tests

To assess the reliability of the baseline regression results and mitigate concerns arising from measurement error and potential endogeneity, this study conducts robustness and endogeneity tests using an alternative measure of digital transformation and an instrumental-variable approach. Measures of digital transformation may capture different dimensions of firms' digital strategies, technological applications, and investments in digital assets. It is therefore important to examine whether the results are sensitive to the specific operationalization of digital transformation. Following prior approaches to measuring firms' digital investment and digital assets (Qi et al., 2022; He & Liu, 2019), Panel A of Table 4 replaces the original Digital variable with the alternative measure Digital_i.

The results show that, in the baseline model with Speed as the dependent variable, the coefficient of Digital_i is 0.038 and is significant at the 1% level. Along the exploitative

innovation pathway, the coefficient of Digital_i on Design is 0.109. When Design is included in the internationalization-speed equation, the coefficients of Design and Digital_i are 0.024 and 0.035, respectively, and both remain significantly positive. Along the exploratory innovation pathway, the coefficient of Digital_i on Invention is 0.199. After Invention is introduced into the outcome equation, the coefficients of Invention and Digital_i are 0.021 and 0.034, respectively, and both are significant at the 1% level. These findings indicate that the direct effect of digital transformation and the two innovation-based mediation paths remain supported when an alternative measure of digital transformation is employed.

Furthermore, to alleviate potential reverse causality and other endogeneity concerns between digital transformation and enterprise internationalization speed, this study employs an instrumental-variable approach. Digital_iv is constructed as the average level of digital transformation among other firms in the same industry and year, excluding the focal firm from the calculation of the industry-year mean. The identification rationale is that a firm’s digital transformation is likely to be influenced by industry-wide digitalization trends and technological diffusion. At the same time, after controlling for the focal firm’s own digital transformation and other firm characteristics, the average digitalization level of its industry peers is assumed not to affect the focal firm’s internationalization speed directly. This exclusion restriction is an identifying assumption of the instrumental-variable strategy and cannot be established solely from the reported second-stage estimates.

Panel B of Table 4 reports the 2SLS estimates using Digital_iv as the instrument for Digital. In the baseline internationalization-speed model, the coefficient of instrumented Digital is 0.115 and is significant at the 1% level. Along the exploitative innovation pathway, the coefficient of Digital on Design is 0.077 and is significant at the 5% level. In the outcome equation containing both Digital and Design, their coefficients are 0.113 and 0.032, respectively, and both are significant at the 1% level. Along the exploratory innovation pathway, the coefficient of Digital on Invention is 0.224. In the corresponding outcome equation, the coefficients of Digital and Invention are 0.108 and 0.035, respectively, and both are significant at the 1% level.

Overall, the direct effect of digital transformation on enterprise internationalization speed and the indirect transmission paths through both innovation modes remain positive and significant when the alternative digital-transformation measure and the instrumental-variable specification are employed. These findings indicate that the main conclusions are not driven solely by a particular measurement choice or model specification. They are also consistent with the view that the strategic value of digitalization is realized through organizational capabilities, knowledge absorption, and resource-reconfiguration processes (Denicolai et al., 2021).

5.2 Heterogeneity Analysis

Table 5 reports heterogeneity results by ownership, firm size, and region. The effect of digital transformation is positive and significant among nonstate-owned firms but insignificant among state-owned firms, suggesting that more flexible governance facilitates the conversion of digitalization into international expansion. By firm size, the effect is positive for large and medium-sized firms but negative for small firms, indicating that resource base and absorptive capacity condition the benefits of digital transformation (Barney, 1991; Teece et al., 1997; Nambisan et al., 2019; Qiao et al., 2024). Regionally, the effect is strongest in western China and insignificant in eastern and central China, suggesting that digitalization may generate larger marginal benefits where initial digital and internationalization foundations are weaker (Meyer et al., 2023). Overall, the heterogeneity results show that the digital transformation–internationalization relationship is context dependent and shaped by ownership, resource endowment, and regional conditions (Bhatti et al., 2022).

6 Discussion

Building upon the resource-based perspective, dynamic capability theory, internalization theory, and transaction cost theory, the mechanism through which digital transformation affects the internationalization speed of firms is systematically examined in this study. A focus on the two mediating paths of exploitative innovation and exploratory innovation, as well as the external contextual role of policy uncertainty, reveals the underlying logic through which firms accelerate internationalization in the digital era.

The empirical results indicate that digital transformation significantly increases firms' internationalization speed, as shown by the baseline coefficient of 0.043 for Digital, with a z-statistic of 3.63 and significance at the 1% level. This finding suggests that digitalization is not merely a tool for increasing the internal operational efficiency. Rather, digitalization facilitates faster entry into and expansion within foreign markets by enhancing cross-border connectivity, resource integration, and organizational responsiveness (Dethine et al., 2020). This mechanism is also consistent with the view that digital platforms and digital ecosystems can reshape firms' internationalization paths (Nambisan et al., 2019). More fundamentally, the relationship between digital transformation and the internationalization speed identified in this study reflects a broader process through which firms reconfigure cross-border knowledge, organizational boundaries, and transaction arrangements in the digital age. Digital technologies not only reduce information search and coordination costs but also enhance the ability of firms to identify international opportunities, integrate heterogeneous resources, and dynamically adjust overseas operations. As a result, internationalization is no longer merely a gradual expansion process but may increasingly take the form of accelerated development built on data, platforms, and organizational flexibility. Moreover, these findings help reconcile prior debates over the contextual heterogeneity and mixed conclusions regarding the internationalization effects of digitalization, suggesting that the positive role of digital transformation in accelerating internationalization does exist but must be understood through specific mechanisms and boundary conditions (Strange et al. 2022; Bhatti et al., 2022; Denicolai et al., 2021).

Furthermore, this study reveals that ambidextrous innovation plays a significant parallel mediating role in the relationship between digital transformation and internationalization speed. The estimated indirect effect through exploratory innovation is 0.0087, compared with 0.0046 through exploitative innovation, indicating a more prominent role for exploratory innovation in this transmission process. This finding indicates that digital transformation not only increases the efficiency with which firms use existing resources through process optimization, knowledge recombination, and

operational improvement but also enhances their ability to develop new products, services, and market opportunities by expanding knowledge-search boundaries, promoting innovation recombination, and renewing organizational capabilities (Lisboa et al., 2011; Lanzolla et al., 2021). The larger estimated indirect effect through exploratory innovation suggests that, in the context of internationalization, the knowledge creation and expansion of innovation boundaries facilitated by digital transformation can be effectively translated into internationalization-speed advantages, while operating together with the efficiency improvements generated by exploitative innovation to facilitate international expansion (Lin & Si, 2019). These findings are also consistent with prior research demonstrating that digital transformation significantly promotes firm innovation and knowledge creation (Liu et al., 2023) and suggest that the reconfiguration of firms' innovation portfolios during digital transformation constitutes an important microfoundation for faster international expansion (Zhang et al., 2023; Chen et al., 2024). In other words, digital transformation enables firms to internationalize more rapidly not simply because it increases the efficiency of existing operations but also because it enhances their capacity to experiment, learn, and reorganize in the face of unfamiliar markets, thereby allowing them to move more quickly from domestic knowledge to international market knowledge, from existing capabilities to new capabilities, and from local optimization to strategic expansion. This finding advances the literature by showing that digital transformation affects internationalization speed not only through efficiency enhancement but also through the capability-conversion process linking knowledge search, innovation, and market expansion.

In addition, the results on policy uncertainty show that policy uncertainty strengthens both the effects of digital transformation on the two innovation modes and the effects of the two innovation modes on internationalization speed. Thus, policy uncertainty does not operate solely as a constraint; it may also strengthen innovation-oriented internationalization by increasing firms' reliance on digital and innovation capabilities. This mechanism suggests that under highly volatile institutional conditions, firms do not necessarily respond only by postponing decisions or reducing investment; instead,

they may become more proactive in using digital technologies to enhance their information-processing capacity, organizational adaptability, and innovation responsiveness and thereby transform external pressure into momentum for driving international expansion through innovation activities (He et al., 2020; Yang et al., 2022; Tang, 2023). In this sense, policy uncertainty in this study functions not merely as a constraint but rather as an external pressure that can stimulate digital responses and capability reconfiguration. This interpretation is consistent with studies showing that uncertainty may suppress investment in some contexts but may also reshape firms' innovation incentives and strategic adjustment when firms possess sufficient digital and organizational capabilities (Bloom, 2007; He et al., 2020; Yang et al., 2022). Thus, the findings enrich the literature by showing that the effect of policy uncertainty depends on whether firms can convert uncertainty into innovation-oriented digital responses. Policy uncertainty encourages firms to consolidate their existing business base through exploitative innovation while creating new competitive space through exploratory innovation, thereby achieving greater acceleration in internationalization under complex conditions.

Combined with the results of the robustness tests and heterogeneity analysis, this study further verifies that the effect of digital transformation on internationalization is not evenly distributed across all firms but is clearly contingent on organizational and environmental conditions. On the one hand, the core findings remain valid after alternative variable measurements and additional control variables, indicating that the effect of digital transformation on the internationalization speed is not a spurious statistical association but rather a robust empirical relationship. On the other hand, the effect is more notable among nonstate-owned firms, large firms, and firms located in western China, suggesting that the benefits of digital transformation still depend on the absorptive capacity, resource base, and support for regional digital ecosystems in firms. These findings in turn indicate that digital transformation is not a universally effective catch-all factor. Notably, whether it can be translated into an internationalization speed-related advantage ultimately depends on the internal capability structures of firms and the developmental contexts in which they are embedded. This conclusion places digital

internationalization within a broader capability- and context-based research agenda and suggests that future studies can further examine how different institutional environments, digital ecosystems, and organizational learning processes jointly shape the speed and quality of international expansion.

6.1 Theoretical Implications

From a theoretical contribution perspective, this study responds to and extends the literature in several respects.

First, regarding the lack of consensus on the relationship between digitalization and internationalization, this study not only confirms the positive effect of digital transformation on the internationalization speed but also indicates that this effect is rooted in the microfoundation of the innovation activities of firms. Unlike studies in which digitalization is merely treated as a technological input or an exogenous condition, this study demonstrates that digital transformation accelerates internationalization because it reshapes firms' knowledge search, resource allocation, and organizational learning processes (Dethine et al., 2020; Strange et al. 2022). Because the empirical results identify both the direct effect of digital transformation and the mediating roles of exploitative and exploratory innovation, this mechanism provides a more process-oriented explanation for the heterogeneous effects of digitalization on internationalization (Lanzolla et al., 2021; Lin & Si, 2019; Strange et al. 2022). More importantly, this study places the internationalization speed within a dynamic chain of resource reconfiguration and capability formation, suggesting that the pace of international expansion of firms is determined not only by external market opportunities but also by the accumulation of internal digital capabilities and the efficiency with which innovation is translated into competitive action. In this sense, this study helps shift the research focus on digitalization and internationalization from simple outcome correlations to the identification of underlying process mechanisms while also offering a clearer capability-based explanation of the internationalization speed in the digital era.

Second, in this study, both exploitative innovation and exploratory innovation are incorporated into a unified analytical framework, and their parallel mediating roles in the relationship between digital transformation and internationalization speed are identified, thereby more closely linking the digitalization literature with research on ambidextrous innovation. Although previous studies have focused on separately examining the relationship between exploitative or exploratory capabilities and internationalization outcomes (Lisboa et al., 2011; Lin & Si, 2019), few have focused on systematically investigating, from a digital transformation perspective, how these two forms of innovation jointly shape the pace of internationalization. The findings of this study reveal that digital transformation not only enhances exploitative innovation but also significantly strengthens exploratory innovation. This finding contributes to the application of dynamic capability theory within the context of digital international business and adds new evidence on how digitalization shapes the internationalization process through the microfoundations of innovation (Teece et al., 1997; Lanzolla et al., 2021). Specifically, the data, platform, and organizational coordination capabilities generated by digital transformation do not automatically translate into international competitive advantage. Instead, they must be converted through innovation activities. Exploitative innovation reflects the deepening use of existing resources and routines by firms, whereas exploratory innovation reflects their active expansion into new knowledge domains and market spaces. Together, these two innovation modes constitute the central bridge through which digital capabilities are transformed into advantages with respect to the internationalization speed.

Third, this study reveals that the mediating role of exploratory innovation is more prominent than that of exploitative innovation, providing an important supplement to the existing literature. Prior research on digital transformation has often emphasized process optimization, efficiency improvement, and enhanced resource allocation (Dethine et al., 2020; Bresciani et al., 2021; Caputo et al., 2021). The present results further show that the estimated indirect effect through exploratory innovation is 0.0087, compared with 0.0046 through exploitative innovation, indicating a more prominent role for exploratory innovation in explaining enterprise internationalization speed.

Because internationalization speed places particular emphasis on market-entry timing, market experimentation, and the development of new opportunities, the knowledge exploration, new-product development, and identification of new market opportunities facilitated by digital transformation can be effectively converted into firms' ability to enter and expand in international markets more rapidly. This finding indicates that the strategic value of digital transformation lies not only in helping firms operate more efficiently but also in enabling them to identify and enter new international opportunity spaces more rapidly. These findings further clarify the role of digital transformation in international business: its significance lies not only in generating operational-efficiency gains but also in facilitating strategic opportunity discovery and innovation-driven capability upgrading.

Finally, policy uncertainty is incorporated into the transmission chain of digital transformation–ambidextrous innovation–internationalization speed, thereby extending the understanding of the boundary conditions surrounding the relationship between digitalization and internationalization. Existing studies have emphasized mainly the inhibiting effects of uncertainty on investment and innovation (Gulen & Ion, 2016; Bloom, 2007). In contrast, this study reveals that in a digital context, policy uncertainty may strengthen firms' tendency to respond to external shocks through innovation. This process suggests that an uncertain environment is not merely an obstacle to the internationalization effects of digitalization but may also serve as a source of pressure that drives firms to accelerate digital responses, reinforce innovation reconfiguration efforts, and increase the speed of international expansion (He et al., 2020; Yang et al., 2022; Tang, 2023). These findings further enrich the contextualized explanation of the relationship between digitalization and internationalization. More broadly, in this study, the external environment is not treated as a static background condition but rather as a dynamic factor that reshapes resource value, capability conversion, and strategic behaviour. As such, this study not only expands the external contextual dimension of research on digitalization and internationalization but also provides new empirical evidence for understanding how firms can achieve capability upgrading through digital transformation under highly uncertain conditions.

6.2 Managerial Implications

From a managerial perspective, firms should not regard digital transformation merely as a technical tool for cost reduction and efficiency enhancement when advancing internationalization. Rather, it should be treated as a strategic investment aimed at strengthening cross-border operating capabilities and accelerating the internationalization process. Firms need to leverage both exploitative and exploratory innovation and allocate digital resources according to their international expansion objectives. Because the exploratory innovation pathway exhibits a relatively large indirect effect, firms may devote additional attention to investment in novel technology development, experimentation with new business models, and the development of new market opportunities, thereby enabling digital capabilities to be more fully converted into future-oriented innovation and international market expansion capabilities. In addition, firms should develop integrated digital-internationalization strategies rather than treating digitalization and internationalization as separate strategic domains. Digital capabilities can strengthen firms' ability to identify, enter, and serve foreign markets, while the market knowledge and resource networks accumulated through internationalization can, in turn, deepen their digital capabilities.

Moreover, firms should pay close attention to the coordinated development of ambidextrous innovation. On the one hand, they can strengthen exploitative innovation through process digitalization, knowledge integration, and organizational optimization, thereby improving operational efficiency, the consistency of products and services, and the cross-border replication of established business models. On the other hand, firms should enhance exploratory innovation through digital-platform connectivity, data analytics, and cross-domain knowledge integration to support the development of new products, services, and market opportunities. Given the relatively prominent transmission role of exploratory innovation in the relationship between digital transformation and internationalization speed, firms may further embed digital resources in R&D activities, market sensing, and business-model design. Market sensing refers to the ability to identify, interpret, and respond promptly to changes in customer demand and competitive signals in target markets. By combining digital

technologies with market-knowledge acquisition, innovation experimentation, and organizational learning, firms can improve their adaptability to unfamiliar international markets and translate digital transformation into differentiated competitive advantages and stronger new-market matching capabilities. In this way, the efficiency and replication advantages generated by exploitative innovation can complement the opportunity-recognition and capability-renewal advantages generated by exploratory innovation, jointly supporting faster international expansion.

When facing policy uncertainty, firms should not rely solely on contractionary strategies. Instead, they should use digitalization to increase organizational resilience and innovation responsiveness, thereby improving their adaptability to complex institutional environments. This process can be achieved by strengthening policy information monitoring, increasing supply chain visibility, optimizing cross-border operational data analytics systems, and establishing more flexible resource allocation mechanisms. In this way, firms can enhance their ability to identify, respond to, and adjust to institutional change. The findings of this study suggest that under certain conditions, uncertainty does not necessarily weaken firms' motivation to internationalize. Instead, uncertainty may encourage firms to undertake more In addition, firms should adopt differentiated digital strategies according to the ownership structure, firm size, and regional conditions. Specifically, nonstate-owned firms can prioritize rapid digital market response and cross-border customer connection, whereas state-owned firms should focus on reducing hierarchical coordination frictions; large firms can build platform-based and globally coordinated digital systems, whereas small and medium-sized firms should adopt lightweight tools that directly support market sensing, customer connection, and product innovation. Nonstate-owned firms can further leverage their institutional flexibility and decision-making agility to accelerate the translation of digitalization into innovation and market responsiveness. In contrast, state-owned firms must improve their internal incentive and coordination mechanisms to reduce the constraints imposed by hierarchical frictions on the effectiveness of digital transformation. Large firms should convert their resource advantages into platform-based, system-wide, and globally coordinated strengths, whereas small and medium-

sized firms are better suited to a more focused and lightweight digitalization path, thereby prioritizing the development of key digital capabilities that support market sensing, customer connection, and product innovation.

Finally, the findings of this study suggest that firms should regard internationalization speed as an outcome of capability rather than simply an outcome of expansion. Truly sustainable acceleration in internationalization is not a matter of speed built on blind expansion but rather a form of high-quality speed grounded in the coupling of digital capability, innovation capability, and environmental adaptability. Accordingly, when promoting internationalization, firms should place greater emphasis on the organizational absorption of digital investment, its conversion into innovation, and its strategic coordination. By establishing a capability loop that links digitalization, ambidextrous innovation, and internationalization, firms can continuously enhance their cross-border competitiveness and resilience in international expansion.

6.3 Limitations and Future Research

The sample period from 2008 to 2022 includes major external shocks, such as the US–China trade conflict and the COVID-19 pandemic. The current analyses do not separately identify the effects of these structural changes. Future research could therefore employ structural-break tests, period-specific regressions, or event-study designs to examine more precisely how the relationship between digital transformation and internationalization speed varies across periods. Fifth, the positive moderating effect of policy uncertainty, derived from the Chinese context, may not generalize to developed economies with more stable policy environments. Cross-country comparative studies would be valuable to establish boundary conditions.

Although the mechanism through which digital transformation affects the internationalization speed is systematically investigated from the perspective of ambidextrous innovation, several limitations remain. First, the sample mainly comprises A-share listed firms but does not include the large number of unlisted SMEs and platform-based firms. Therefore, the external validity of the conclusions must still

be verified across different firm types and national contexts. Second, the core variables are established mainly from annual report texts and patent applications. Although these measures can capture digital transformation, ambidextrous innovation, and policy uncertainty to a considerable extent, measurement error may still exist. Future research may aim to combine questionnaires, managerial interviews, platform behavioural data, or cross-national firm-level and manager-level data, such as survey data on digital capability, R&D collaboration, overseas market entry decisions, and innovation project records, to provide a more detailed characterization of digital capabilities and innovation activities. Third, this study focuses mainly on the mediating role of ambidextrous innovation and the moderating role of policy uncertainty but does not systematically incorporate other potential paths and boundary conditions, such as organizational resilience, international network embeddedness, platform dependence, or governance mechanisms. Future research may aim to reveal the multidimensional logic through which digital transformation affects the internationalization processes of firms by accounting for more comprehensive mechanisms and contextual variables.

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Table 1. Descriptive statistics and correlations

Panel A. Descriptive statistics

Variable	Obs.	Mean	Std. dev.	Min.	Max.
Digital	9,306	2.387	1.220	0	6.312
Speed	9,306	0.534	1.047	0.0026	8
Size	9,306	22.507	1.391	19.446	28.637
Age	9,306	2.916	0.337	0.693	4.025
Design	9,306	1.648	2.148	0	9.888
Invention	9,306	2.275	1.997	0	10.810
ROAB	9,306	0.0182	0.0735	-0.0891	0.1518
Dual	9,306	0.335	0.472	0	1
Fepu	8,541	1.7713	1.6804	0	15.3846

Panel B. Correlation matrix

Variable	Digital	Speed	Design	Invention	Size	Age	ROAB	Dual	Fepu
Digital	1								
Speed	0.0640	1							
Design	0.0787	0.0878	1						
Invention	0.1377	0.0608	0.3969	1					
Size	-0.0162	-0.1055	-0.1338	0.1269	1				
Age	0.0372	-0.2030	-0.0005	0.0669	0.1509	1			
ROAB	-0.0692	0.0349	-0.0249	-0.0566	-0.0358	-0.1463	1		
Dual	0.0987	0.0721	0.0548	0.0052	-0.2005	-0.0954	0.0113	1	
Fepu	-0.0674	0.0160	0.0061	0.0575	0.1489	0.1212	-0.1350	-0.0479	1

Notes: Digital = digital transformation; Speed = speed of internationalization; Design = exploitative innovation; Invention = exploratory innovation; Size = firm size; Age = firm age; ROAB = return on assets; Dual = CEO-chair duality; Fepu = firm-level policy uncertainty.

Table 2. Baseline and mediation results

Variable	(1) Speed Baseline	(2) Design Exploitative innovation	(3) Speed Design added	(4) Invention Exploratory innovation	(5) Speed Invention added
Digital	0.043*** (3.63)	0.114*** (5.22)	0.041*** (3.42)	0.191*** (9.49)	0.039*** (3.31)
Design			0.023*** (4.27)		
Invention					0.021*** (3.72)
Size	-0.127*** (-8.56)	-0.106*** (-4.07)	-0.124*** (-8.40)	0.168*** (7.36)	-0.130*** (-8.78)
Age	-1.354*** (-27.85)	0.318*** (3.63)	-1.358*** (-28.00)	0.416*** (5.22)	-1.360*** (-28.02)
ROAB	-0.223* (-1.90)	-0.247 (-1.09)	-0.214* (-1.82)	-0.871*** (-3.94)	-0.201* (-1.71)
Dual	0.004 (0.15)	-0.007 (-0.14)	0.005 (0.19)	0.044 (0.89)	0.004 (0.16)
Constant	7.470*** (24.85)	2.890*** (5.39)	7.376*** (24.62)	-3.203*** (-6.61)	7.509*** (25.03)
Observations	9,306	9,306	9,306	9,306	9,306
Controls	Yes	Yes	Yes	Yes	Yes

Panel B. Bootstrap mediation tests

Indirect path	Indirect effect	Bias-corrected 95% CI	Conclusion
Digital -> Design -> Speed	0.0046	[0.0024, 0.0071]	Significant mediation
Digital -> Invention -> Speed	0.0087	[0.0056, 0.0130]	Significant mediation

Notes: z-statistics are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Control variables include Size, Age, ROAB, and Dual unless otherwise noted.

Table 3. Moderating effects of policy uncertainty on the innovation-based transmission paths

Variable	Exploitative innovation path (1) Design H4a	Exploitative innovation path (2) Speed H4b	Exploratory innovation path (3) Invention H4c	Exploratory innovation path (4) Speed H4d
Digital	0.124*** (5.51)	--	0.199*** (9.48)	--
Design	--	0.020*** (3.59)	--	--
Invention	--	--	--	0.019*** (3.18)
Fepu	0.049*** (3.77)	0.014** (2.07)	0.021* (1.67)	0.018*** (2.68)
Digital x Fepu	0.058*** (6.12)	--	0.034*** (3.71)	--
Design x Fepu	--	0.021*** (9.31)	--	--
Invention x Fepu	--	--	--	0.018*** (7.06)
Size	-0.124*** (-4.68)	-0.120*** (-8.08)	0.166*** (7.16)	-0.126*** (-8.48)
Age	0.290*** (3.23)	-1.299*** (-26.38)	0.384*** (4.69)	-1.303*** (-26.39)
ROAB	-0.318 (-1.28)	-0.182 (-1.42)	-1.024*** (-4.18)	-0.132 (-1.03)
Dual	0.028 (0.51)	0.020 (0.68)	0.055 (1.06)	0.015 (0.51)
Constant	3.256*** (5.92)	7.096*** (23.40)	-3.112*** (-6.26)	7.232*** (23.80)
Observations	8,541	8,541	8,541	8,541
Overall R-squared	0.0245	0.0630	0.0448	0.0587
Adjusted R-squared	--	--	--	--
Wald chi2	106.72	1344.83	313.61	1294.96

Notes: Values are coefficients with z-statistics in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Fepu = firm-level policy uncertainty. Columns (1) and (3) test first-stage moderation from digital transformation to innovation; columns (2) and (4) test second-stage moderation from innovation to internationalization speed.

Table 4. Robustness and endogeneity tests

	Model
Panel A. Alternative digital-transformation measure (Digital_i; N = 9,306)	

	Model
Baseline model	

	Model
Mediator equation: exploitative innovation	

Outcome equation: exploitative innovation added

Mediator equation: exploratory innovation

Model

Outcome equation: exploratory innovation added	
Panel B. Instrumental-variable approach (Digital instrumented by Digital_iv; N = 9,280)	
Baseline model	

Model

	Model
Mediator equation: exploitative innovation	

Outcome equation: exploitative innovation added

Mediator equation: exploratory innovation

Model

Outcome equation: exploratory innovation added

Notes: Panel A replaces Digital with Digital_i and reports random-effects GLS estimates. Panel B instruments Digital using Digital_iv and reports 2SLS estimates. z-statistics are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. All models include Size, Age, ROAB, and Dual.

Table 5. Heterogeneity tests

Dimension	Subsample	Digital coefficient	t-statistic	Observations	R-squared
Ownership	State-owned enterprises	-0.008	-0.810	4,947	0.0317
Ownership	Non-state-owned enterprises	0.087***	3.635	2,187	0.0857
Firm size	Large-size group	0.061***	3.77	3,102	0.050
Firm size	Middle-size group	0.038**	2.58	3,102	0.050
Firm size	Small-size group	-0.034**	-2.28	3,102	0.030
Region	Nationwide	0.019**	1.98	9,306	0.049
Region	Eastern China	0.012	1.19	7,647	0.049
Region	Central China	0.027	0.75	975	0.042
Region	Western China	0.080**	2.04	673	0.073

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. The table reports the coefficient of Digital in each subsample. Control variables are included but not tabulated to preserve space.

Data Availability

The de-identified analytical datasets supporting the findings of this study are provided in the supplementary materials accompanying this submission. The shared materials include the datasets used for the main-effect and baseline analyses, mediation-effect analyses, moderation-effect analyses, total-effect analyses, endogeneity tests, and robustness tests. Documentation concerning variable definitions, measurement procedures, coding rules, data transformations, model specifications, and the relevant statistical analysis scripts is also provided.

To protect data privacy and comply with applicable data-use restrictions, certain raw source files and intermediate or process-level data that may contain identifiable or otherwise protected information are not publicly available. These materials are securely retained by the research team. The de-identified analytical datasets provided in the supplementary materials are sufficient for verifying the principal empirical results reported in the manuscript.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- DTdata.xlsx
- HSSCfinalsupplementarytableS1.docx