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Technical founders, digital transformation and corporate technological innovation: empirical evidence from listed companies in China's STAR market

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Abstract

Technology entrepreneurship and corporate innovation are important for the development of indigenous innovation. In the digital age, founders are subject to fundamental changes in their strategy choices, which in turn affect corporate innovation performance. This paper aims to explore the strategic choices adopted by technical founders of listed companies in China's STAR market to reap the rewards of innovation in a digital context. Based on the annual reports of 124 listed companies in China's STAR Market, this paper applies machine learning methods to quantify digital transformation of enterprises, and empirically analyzes the relationship between technical founders and innovation performance by constructing a moderated mediating model. Our results show that companies with technical founders are more likely to adopt digital transformation and thus show better innovation performance. In terms of heterogeneity, the empirical results demonstrate that firms with technical founders show better performance in digital transformation, followed in turn by those with business founders and academic founders. Both the positive relationship between enterprise digital transformation and innovation performance and the mediating effect of digital transformation are positively moderated by venture capital or private equity support. The findings reveal the microscopic mechanism of the role of technology-based founders on corporate innovation performance and hence have practical implications for promoting corporate digital transformation and enhancing firm technological innovation.

Keywords Technical founder · Technological Innovation · Technology entrepreneurship · Digital transformation · Innovation performance · STAR Market

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Introduction

Science and technological innovation are important not only for economic and social development, but also for the long-term competitive advantage of entrepreneurial enterprises. Since 2012, China has adhered to the innovation-driven development strategy and strived to build an innovative economy. According to China's ***14th Five-Year Plan*** (2021–2025) and ***2035 Vision*** the country will improve the market-oriented mechanism of technological innovation, strengthen the status of enterprises as the principal engine of invention and promote the concentration of various innovation resources among enterprises. In the so-called VUCA (volatility, uncertainty, complexity, and ambiguity) era, the exploration, development and application of technology entrepreneurship are contributing to business innovation and social progress (Troise et al., 2022). The current socioeconomic environment is invariably influenced by the emergence and rapid changes of new technologies, such as social media, big data, cloud computing, artificial intelligence and blockchain, which provide small and medium enterprises (SMEs) with a wide range of entrepreneurial opportunities and cheap access to information (Elia et al., 2020; Rodriguez-Lluesma, García-Ruiz and Pinto-Garay, 2021). It is apparent that in this process, firms are involved in the transformation of critical business operations, which in turn affects their innovation performance (Rippa & Secundo, 2019; Oppong, Singh and Kujur, 2020; Zhang, van Gorp and Kievit, 2022).

Research on technology entrepreneurship can be broadly divided into two categories. The first category focuses on how, why, and when technology entrepreneurship affects the socio-economic development of a region. This, of course, includes social performance at the macro level and firm innovation from the micro perspective. Scholars generally believe that technology entrepreneurship is one of the significant sources of economic growth and contributes significantly to wealth and job creation (Mosey et al., 2017; Gu & Wang, 2022; Mackiewicz & Błoch, 2022). It is argued that innovative entrepreneurship and the development of new technologies contribute to technological change, which facilitates productivity growth and thus the upward shift of national production frontiers (Lafuente et al., 2020).

The second category explores the formation of technology entrepreneurship and interdependence between technology path and small technology firm formation and growth. Previous research has established that external organizations, national entrepreneurial culture, resource environment and regional knowledge production all influence the creation and development of new technology firms (Colino et al., 2014; Seguí-Mas et al., 2018; Hülsbeck & Pickavé, 2014). Furthermore, from an internal organizational perspective, the entrepreneur is a decisive factor influencing technology entrepreneurship, which involves entrepreneurial traits such as education background (Fayolle et al., 2021; Bolzani et al., 2021; Blankesteijn et al., 2021), human capital (Ganotakis et al., 2012; Zane, 2022), and entrepreneurial capability (Reese et al., 2021). As communication technologies and digitalization have evolved, the external environment driving technology entrepreneurship has also changed. Scholars are not only interested in how supportive regulatory and normative environmental conditions affect the configuration of technology entrepreneurship initiatives but also began to explore the link between digital transformation and technology entrepre-

neurship innovation (Hanoteau & Rosa, 2019). Several studies show that the organizational will of start-ups is primarily influenced by the individual traits of technology entrepreneurs. However, we know very little about the mechanism of how technical founders affect innovation performance of enterprises from the founders' perspective. In particular, there is still a gap in research on the strategic choices adopted by founders of technology start-ups to reap the rewards of innovation in the context of digitalization.

To fill the above-mentioned research gap, this paper adopts a text analysis approach to measure digital transformation of enterprises, and empirically analyzes the relationship between technical founders and innovation performance by adopting a moderated mediating model. Our empirical results indicate that digital transformation mediates the positive relationship between technical founders and innovation performance. Therefore, this study makes a major contribution to research on upper echelons theory and imprinting theory. It shows that technical founders tend to favor digital transformation and hence confirms the impact of founder identity on the digital transformation of companies. Meanwhile, the paper provides new insight into technology entrepreneurship. It expands the literature on the interdependence between technology path and innovation and explains the dynamics underlying the differential performance of firm innovation performance from the perspective of founder heterogeneity. In addition, this study presents a comparison of the differences in innovation performance between technical founders, academic founders and business founders, and examines the microscopic mechanism of the role of technology-based founders in corporate technological innovation.

The remainder of this paper is organized as follows. In Sect. 2, we describe the literature review and hypothesis development. Section 3 provides a description of the models, data collection and variable measurement. In Sect. 4, we present the empirical results and interpretation. The robustness of the baseline modelling results is checked in Sect. 5. Finally, we present the conclusions and discuss the contributions, implications and limitations of this paper in Sect. 6.

Literature review and hypotheses development

Technical founder and enterprise innovation performance

According to the upper echelons theory, CEOs' values, experiences and personalities may influence their access to information in decision-making, which in turn affects the organizational actions and performance (Wei et al., 2018; Wang & Chen, 2020). Specifically, the behavior of a CEO is based on his or her personal, individualized interpretation of the strategic environment. The individualized cognitive construction of the external environment stems from the combined influence of the CEO's experience, values, and personality traits. Technical founders, as the protagonists of corporate innovation investment and decision-making, are one of the most innovative groups (Sun et al., 2022), often serving as both chairman and CEO. Studies have shown that the greatest strength of technology entrepreneurs, whether working alone or in teams, is that they usually have a deep technical understanding of their business

foundation and therefore have a clear understanding of how the new technologies they create can be applied to the business environment (Oakey, 2012). In the actual R&D process, the technical founder spontaneously participates in innovation activities and shows better innovation performance due to their dual roles of R&D and management (Jiang et al., 2021).

Furthermore, companies with technology-based founders tend to have coordinated IT teams and establish a communication environment with customer interaction, and once changes in user value attributes are identified, they may launch technology upgrades, thus showing better innovation performance (Qian et al., 2021). Therefore, when founders with technical backgrounds are involved in entrepreneurial activities, their knowledge capabilities and technical skills can be transformed into intangible assets that are constantly used and updated during the entrepreneurial process, opening up more innovative fields and providing high-quality problem solutions for corporate innovation (Marvel et al., 2020). Similarly, a study by Yeganegi et al. (2021) validates that potential technology entrepreneurs are at an advantage when information is more readily available, leading to higher technology entrepreneurship. Nielsen's (2015) study also shows that technical entrepreneurs are found to perform better in both profitable and uncertain industries, while non-technical entrepreneurs perform better only in profitable industries. Therefore, we may conclude that technical founders are able to leverage their technical expertise, innovative thinking and entrepreneurial experience to effectively organize and manage teams, identify market opportunities and continuously drive technological innovation. These also explain why technical founders are the primary drivers of superior technological innovation performance. Based on the above arguments, we propose the following hypothesis.

Hypothesis 1 *Firms led by technical founders show better innovation performance than those led by non-technical founders.*

Technical founder and enterprise digital transformation

Imprinting theory suggests that individuals and organizations may experience many sensitive periods during their development, generating imprints that match environmental characteristics and persistently influence individual and organizational decision-making behavior (Pieper et al., 2015). The entrepreneurial imprint of technical founders also has an impact on the enterprise's digital transformation. Numerous studies highlight that digital transformation should be a top management priority and a defining trait of corporate business strategy. Companies raising digital consciousness may get one step ahead on their transformation journey (Saarikko et al., 2020; Porfírio et al., 2021; Gurbaxani & Dunkle, 2019).

Since technology-based founders are relatively proactive and adaptive in the face of digital changes and dynamic environments, they are more likely to leverage their resources to spur business growth (Yeganegi et al., 2021). The study by Weber, Büttgen and Bartsch (2022) indicates that leadership is crucial to the success of digital transformation in companies. The skills and competencies of individual founders have a significant impact on the acceptance of digital transformation (Chatterjee et

al., 2022). At the innovation capabilities level, technical founders are specialized in integrating and leveraging digital technologies for innovation. They transform organizations into flexible enterprises, thus reducing the possibility of rigidity caused by digital technologies (Tsou and Chen, 2022). At the same time, as organizations go digital, technical founders understand the enormous challenges that technological change poses to their employees. They strengthen employees' belief in technological change and adopt a set of HR practices that facilitate innovative employee behavior, thus achieving a match between employee competencies and digital technologies (Nicolás-Agustín et al., 2021; Solberg et al., 2020; Kozanoglu and Abedin, 2021). Therefore, this people-oriented leadership behavior can buffer the potential negative effects of digital transformation-oriented leadership behavior, which is mandatory to stay competitive in the digital era (Weber et al., 2022).

In addition, at the level of corporate R&D and cooperation, technical founders have rich knowledge assets and are more familiar with R&D and production processes, so they can better grasp the technological development and cross-organizational collaboration. At the policy perception level, the government encourages technological innovation by giving SMEs guidance, support and incentives. Accordingly, technical founders can obtain relatively more financial support and R&D subsidies from various policies, alleviate corporate financing constraints, increase investment in digital technology exploration, and tend to make digital transformation decisions. Therefore, the educational background and experience of technical founders in the technology field imprint a deeper understanding of digital and information technology and enhance their forward-looking vision and sensitivity towards technology innovation and application. Moreover, the inventor identity of technical founders in technology exploration and exploitation also makes them to pay more attention to the application and practice of technology and display greater tolerance for failure and a tendency to integrate technological innovation with business innovation. All these are helpful for the identification and pursuit of opportunities for digital transformation (Bostan & Mian, 2019). Based on these arguments, we propose the following hypothesis.

Hypothesis 2 *Firms led by technical founders are more likely to choose digital transformation than those led by non-technical founders.*

Digital transformation and enterprise innovation performance

Digital transformation is a revolution and restructure that is driven and built on digital technology. Within the enterprise, digital transformation is defined as an organizational shift towards big data, business analytics, cloud computing, mobility, and social media platforms. The utilization of digital technologies has been widely studied, and scholars have explored the relationship between digital transformation and corporate innovation performance from different perspectives. Drawing on the resource dependence theory, Li, Rao, and Wan (2022) examined the impact of digital technology on corporate innovation using data from Chinese A-share listed manufacturing firms from 2011 to 2019 and found that corporate digital transformation has a significant positive effect on corporate innovation. Zhao et al. (2022), using a fixed

effects model based on a panel of 584 listed manufacturing firms in China from 2016 to 2020, also found that digital transformation significantly improves firms' innovation capabilities. Furthermore, Tsou et al.'s (2022) survey of 227 Taiwanese financial industry regulators found that digital technology adoption facilitated corporate digital transformation and organizational innovation, which in turn influenced corporate innovation performance. Similarly, Peng and Tao's (2022) study revealed that digital transformation not only significantly improved firm performance but also further motivated firms to innovate. In contrast, Lin and Yi (2022) explored the combination of antecedent conditions for digitally enabled enterprise innovation through the lens of configuration and holism. Their results show that digital infrastructure is the underlying support for digitally enabled enterprise innovation, while cross-boundary collaboration plays a crucial role in innovation.

Despite the above scholars affirming the positive effects of digital transformation on corporate innovation, there are also scholars who find that digital transformation cannot play a significant role as a single tool and must be synergized with technology, information, institutions, and policies to be sustainable. Nasiri et al. (2020) show that the digital transformation of companies alone cannot improve innovation performance and needs to be combined with intelligent technologies to achieve this goal. A similar view is that firms can apply digital technologies to enhance novel internal and external processes and integrate them into new business models, thereby advancing a new wave of innovation in the firm (Ricarda et al., 2021). Wu et al. (2022) also specifically highlight resource integration as a bridge between digital capabilities and open innovation. Digital transformation enables companies to access and transfer knowledge both within and outside the company, which facilitates resource matching and utilization. In summary, the above-mentioned scholars have clarified from the perspective of resource integration that the application of digital technology can directly help enterprises to obtain valuable information resources, reduce their innovation risks, further optimize and improve the allocation efficiency of enterprise resources, and enhance innovation performance. Based on the above arguments, we propose the following hypothesis.

Hypothesis 3 *Digital transformation is positively related to firm innovation performance.*

The above hypotheses together demonstrate the mediating roles of digital transformation. Specifically, organizations and entrepreneurs with a consciousness of digital transformation are more likely to build digital technology infrastructure. In addition to the technical expertise and human capital that technical founders have, the rapid changes in technology are forcing them to think outside the box. Meanwhile, the external and internal relationships of digital technology support in companies and the strategic alignment of digital technology with business enhance the ability of entrepreneurs to cope with the turbulence of the market environment and are important for companies to achieve innovative performance (Li et al., 2020). Therefore, when external technology changes, technology founders have a positive impact on innovation performance by virtue of digital transformation technology application and information integration and adjusting innovation strategies accordingly to accel-

erate resource sharing within the organization, shorten innovation cycles, and reduce corporate innovation costs (Chierici et al., 2021). Based on the above arguments, the following hypothesis is proposed.

Hypothesis 4 *Digital transformation mediates the relationship between technical founders and firm innovation performance.*

It has been shown that venture capital (VC) and/or private equity (PE) plays a role in financing, selection, information gathering, embedding and signaling in the growth of start-ups (Ferrary & Granovetter, 2009). Among them, business and technical embeddedness of venture capital is an effective means to enhance the competitive development and innovation performance of start-ups, which explains why VC/PE support empowers corporate digital transformation and technological innovation (Andersson et al., 2002). Most studies have confirmed that network embeddedness is positively related to firms' innovation capabilities and innovation performance. Dyer and Singh (1998) believe that network embeddedness enriches firms' knowledge sharing routes and enhances corporate effective governance and complementary resources through joint learning and knowledge interaction. Furthermore, VC/PE-backed companies typically exhibit certain characteristics in their board structure, such as a lower number of internal and instrumental directors, and a higher number of independent board members (Baker & Gompers, 2003). This board structure can promote innovation performance. Research has shown that independent board members usually possess broader experience and expertise which enable them to provide valuable strategic advice and market insights to companies, and thereby facilitate the identification and development of new opportunities (Li et al., 2020). Therefore, on the one hand, Sci-Tech enterprises leverage the relational capital and structural optimization of the network embedded by VC/PE and hence draw on novel external resources to promote digital transformation and technological innovation. On the other hand, VC/PE participation in corporate governance may affect the board structure, provide more support and guidance to the management and operations of a company, help the company optimise its innovation processes and resource allocation, and thus maximise the promotion of digital transformation in innovation. Based on the above arguments, the following hypothesis is proposed.

Hypothesis 5 *VC/PE support positively moderates the mediating role of digital transformation in the relationship between technical founders and firm innovation.*

Finally, Fig. 1 is presented to summarize the above-discussed conceptual framework and show the hypotheses to be tested in the empirical analysis.

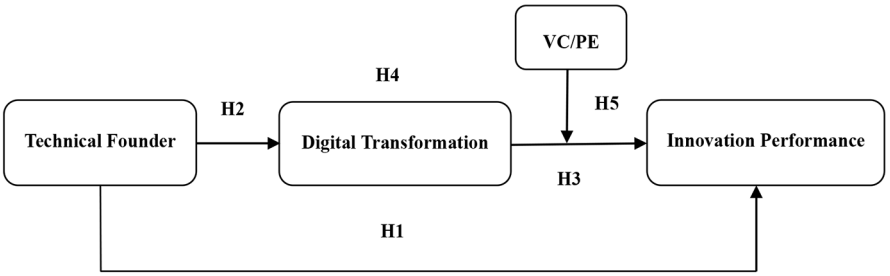

Fig. 1 Conceptual framework and hypotheses

The modelling and data issues

The empirical models

The following empirical models are adopted to analyze the relationships among technical founders, digital transformation, and innovation performance:

$$Innovation = \alpha_0 + \alpha_1 Technical + \alpha_2 Controls + \varepsilon \quad \text{(I)}$$

$$Digitalization = \beta_0 + \beta_1 Technical + \beta_2 Controls + \delta \quad \text{(II)}$$

$$Innovation = \gamma_0 + \gamma_1 Technical + \gamma_2 Digitalization + \gamma_3 Controls + \varphi \quad \text{(III)}$$

where *Innovation* is the dependent variable representing firm innovation performance, *Technical* is the independent variable capturing the role of technical founders, *Digitalization* is the mediating variable which quantifies digital transformation and *Controls* represent a set of control variables. ε and δ are the error terms.

To test whether the mediating effects of digital transformation are moderated by VC support, the following moderated mediation model is considered (Muller et al., 2005):

$$Innovation = \lambda_0 + \lambda_1 Technical + \lambda_2 Digitalization + \lambda_3 VC + \lambda_4 Digitalization \times VC + \lambda_5 Controls + \pi \quad \text{(IV)}$$

where VC is a moderating variable and π *is* the error term.

Data sources

In this study, the initial research sample covers enterprises registered and declared on the Science and Technology Innovation Board (STAR Market) from March 22, 2019 to May 1, 2021. The sample excludes state-owned enterprises controlled by either central or local governments and enterprises with missing relevant variables. The final sample has 197 observations from 124 companies listed on the STAR Market. The data of corporate innovation performance is obtained from the patent library

of the State Intellectual Property Office of China and Qichacha. The founder characteristics and corporate financial data are mainly obtained from founder CVs and company prospectuses. The measurement of digital transformation is based on textual analysis of corporate annual financial reports; and the data of VC/PE support is obtained from the PEdata of Zero2IPO. The complete list of data sources is detailed in Table 1.

Table 1 Variable definition and measurement

Type	Variable name	Definition	Source
Dependent variables	Innovation Performance	The log of invention and utility model patents	Patent Library of the State Intellectual Property Office of China and Qichacha
	Innovation Quality	The log of invention patents	
	Innovation Quantity	The log of invention, utility model and design patents	
Independent variables	Academic	1 for academic founders; 0 otherwise	Founder resume
	Business	1 for business founders; 0 otherwise	
	Technical	1 for technical founders; 0 otherwise	
Mediating variable	Digital Transformation	The integration of digital technology into mindsets, business and operational models	Annual reports of listed companies
Moderating variable	VC/PE	1 for companies with VC/PE support; 0 otherwise	PEdata
Control variables	Male	1 for male founder; 0 otherwise	Founder resume
	Age	Age of the founder	Founder resume
	Education	Founder's education level, 5 for PhD, 4 for master, 3 for bachelor, 2 for junior college, 1 for high school and below	Founder resume
	Asset	Log of total assets	Prospectus
	Overseas	1 for founders with overseas background; 0 otherwise	Prospectus
	Duality	1 for founders who are also chairmen and CEOs; 0 otherwise	Qichacha
	ROA	Net income / Total assets	Prospectus
	LEA	Total liabilities/ Total assets	Prospectus
	ONCF	Operating activities net cash flows	Qichacha

Variable measurement

Innovation is the main dependent variable which measures corporate innovation performance and is used to evaluate the efficiency and effectiveness of firm innovation activities. It belongs to a specific form of organizational performance (Wang & Hu, 2020). In this paper, we use the total number of invention and utility patents granted in the current year to measure the innovation performance. Like Hu, Pan and Huang (2020), we also use the invention patents and all patents (the invention, utility model and design patents) in the current year as proxy variables for the quality and quantity of innovation of enterprises.

Technical represents technical founders who are business founders with technical professional background and creative characteristics. They often have a deep technical understanding of their business basis and of how the new technology they create is applied to the business environment. This study classifies founders into academic founders, business founders, and technical founders. Specifically, we first structured and stored the textual information of the collected CVs of 2775 founders. We then invoke the LDA topic model to train the corpus and use the Coherence Model to evaluate the model for consistency under a number of topics (for details, refer to Mimno et al., 2011). After several training sessions, the number of topics with the highest consistency score is determined to be 5, and then the initial topic type and the corresponding top 20 representative words with the highest frequency of occurrence are selected to obtain the initial seed word set. Then, we combine the linkage of keyword lexical meanings among topics and classify them into three identity attributes, namely, technical, business, and academic. Next, we supplemented the candidate word sets using core vocabulary semantics and literature related to founder identity. Finally, the construction of the final lexicon of the founder identity was completed. Based on the built-in split-word dictionary in LDA (see Appendix 1), we adopt the jieba library to split-word process all founder resumes and count the number of keyword disclosures (see Appendix A) from academic, business, and technical categories, respectively, for each founder. The highest number determines the founder's identity. For founders with the same word frequencies (no clear identification of the highest number), we manually check their resumes and integrate relevant information from the official company websites, Wind's person database, and online news to ultimately determine their founder identity.

Digitalization is a proxy for digital transformation. According to Wu et al. (2021), digital transformation is measured in two dimensions, namely digital technologies and digital application (see Appendix B). Digital technologies include artificial intelligence, blockchain, cloud computing, and big data technologies and the application of digital technologies is based on the commercial operation of these technologies. Specifically, we employed the digital transformation lexicon developed by Wu et al. (2021) as the initial corpus and utilized the Chinese pre-trained BERT model to construct the word vector for each keyword (for details about BERT, refer to Devlin et al. 2018). Subsequently, we incorporated these digital transformation keywords into the jieba segmentation library and applied accuracy mode and lcut algorithm to tokenize 197 annual reports of companies. Stopword removal was conducted to construct the vocabulary of the annual reports. Next, we extracted words from the annual report

vocabulary that had 80% similarity to the digital transformation word vectors, and manually screened and combined them with expert opinions, resulting in 24 extra keywords representing digital transformation in companies (see Appendix B), which were added to the built-in dictionary with 76 keywords (thus a total of 100 keywords are used). Finally, we counted the frequency of disclosure for these keywords from the company business summary, discussion and analysis of operating conditions, and corporate governance to determine the level of digital transformation in companies. This gives us the definition of Digital Transformation I (Digitalization_1). At the same time, we also constructed Digital Transformation II (Digitalization_2). In addition, we extracted the before and after texts related to digital transformation from manual reading and evaluation and eliminated the number of word frequencies that were not associated with digital transformation strategies, operations and business models. We use this new data to construct Digital Transformation II (Digitalization_2).

VC reflects support from venture capital or private equity which is the primary source of equity financing for technology start-ups. Companies with technical founders are uniquely positioned for equity financing, as they not only understand the market and customer needs, but also track cutting-edge technology to keep up with the times. Therefore, VC/PE support alleviates the problem of financing availability on the one hand and provides heterogeneous information resources on the other hand. *VC* has a value of 1 if a firm gets VC/PE support and 0 otherwise.

Like Islam et al. (2022) and Jiang, Wang, and Zeng (2021), variables such as the founder characteristics and basic financial indicators of the firm which are likely to affect the firm's innovation performance, are used as control variables in this study. At the individual level, we control the age, gender, education, overseas background, and duality of the founder. At the firm level, we control firm scale, ROA, LEA and ONCF. The definitions of the variables are shown in Table 1.

Descriptive statistics and correlation tests

Table 2 reports the descriptive statistics of the variables. The percentage of technical founders is 41.2%, and the percentage of academic and business founders is 22.3% and 36.5%, respectively. The average keyword frequency of digital transformation is 70.44 and 50.09, which reflects the active digital transformation for the listed enterprises in China's STAR Market. However, the standard deviations are 84.65 and 67.79 respectively, indicating that there are large differences in digital transformation among enterprises. In addition, the sample founders are generally middle-aged (mean = 52.43) and predominantly male (mean = 0.959) with a master's degree (mean = 3.888). The founders with overseas background accounted for 28.4%, and most of them are also chairmen and CEOs (mean = 0.619). In addition, this paper also tested the variance inflation factor, whose maximum value is 1.99, which is much lower than the critical value of 10.00, indicating that no significant covariance exists among the independent variables.

The results of the correlation analysis are presented in Table 3. It is shown that *technical* is significantly and positively correlated with firm *innovation* performance at a 0.1% level. *Technical* is significantly and positively correlated with *digital* transformation at a 0.1% level. *Digital* transformation is also positively correlated

Table 2 Descriptive statistics and VIF test

Variables	N	Mean	SD	Min	Max	VIF
Invention patent	197	28.36	53.7	0	449	-
Utility patent	197	12.5	28.72	0	286	-
Design patent	197	2.975	8.49	0	68	-
Academic	197	0.223	0.418	0	1	-
Business	197	0.365	0.483	0	1	-
Technical	197	0.411	0.493	0	1	1.15
Digitalization_1	197	70.44	84.65	1	417	1.22
Digitalization_2	197	50.09	67.79	0	330	-
Age	197	52.43	7.314	37	76	1.24
Male	197	0.959	0.198	0	1	1.04
Education	197	3.888	0.983	1	5	1.48
Overseas	197	0.284	0.452	0	1	1.47
Duality	197	0.619	0.487	0	1	1.14
VC/PE	197	0.919	0.274	0	1	1.13
Asset	197	12.16	0.915	10.37	16.17	1.92
LEA	197	0.206	0.149	0.0198	0.697	1.22
ROA	197	0.0639	0.135	-1.008	0.48	1.25
ONCF	197	2.528	6.765	-5.98	43.08	1.99

with firm *innovation* performance at 0.1% level. The above results tentatively verify hypotheses H1, H2 and H3.

Empirical results

Benchmark regression analysis

Table 4 reports the results of the benchmark regression of the relationship between the technical founder and firm innovation performance. Model (1) is to verify the relationship between technical founders and firm innovation performance without control variables. Model (2) reflects that technical founders positively affect firm technological innovation at the 5% level (regression coefficient of 0.484), which supports hypothesis H1. Meanwhile, compared with Model (1), the R^2 in Model (2) increases, which also verifies the rationality of the model construction. The above findings validate that firms led by technical founders show better innovation performance.

Analysis of mediating effect of digital transformation

Model (3) in Table 4 is to test the relationship between the technical founder and digital transformation. The results show that the effect of technical founders on digital transformation is positive and significant at the 5% level, which reveals that firms with technical founders tend to favor digital transformation. Furthermore, we compare the differentiated performance of different types of founders on digital transformation. Model (4) further reveals the relationship between founders and corporate digital transformation. The results show that technical founders' companies have the

Table 3 Summary of the correlation test

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
Innovation	1												
Technical	0.200***	1											
Digitalization_1	0.224***	0.212***	1										
Age	-0.059	-0.163**	-0.349***	1									
VC/PE	0.182**	0.097	-0.043	0.028	1								
Male	0.137*	-0.089	0.126*	-0.013	-0.061	1							
Education	-0.054	0.137*	-0.053	0.05	0.269***	-0.076	1						
Overseas	-0.134*	-0.069	-0.128*	0.233***	0.023	0.016	0.439***	1					
Duality	0.058	0.082	0.017	-0.098	-0.042	-0.002	-0.036	0.193***	1				
Asset	0.277***	0.074	0.052	-0.033	0.083	0.021	0.025	-0.024	-0.153**	1			
LEA	0.07	-0.038	0.055	-0.029	0.121*	0.007	-0.053	-0.102	-0.05	0.314***	1		
ROA	0.092	0.120*	0.115	-0.111	-0.092	-0.007	-0.059	-0.098	-0.073	-0.01	-0.214***	1	
ONCF	0.081	0.062	0.118*	-0.033	0.021	0.05	-0.131*	-0.079	-0.092	0.637***	0.220***	0.247***	1

most prominent digital transformation, followed in turn by companies with business and academic founders. The above results confirm hypothesis H2.

To examine the mediating effect of digital transformation, we add both technical founders and digital transformation to model (5) to test their effects on firm innovation. The results show that the regression coefficient of digital transformation is 0.188 and significant at the 5% level. Model (5) also illustrates the regression coefficient of technical founders on firm innovation performance is 0.396 at the 5% significance level, which is smaller than the benchmark regression of 0.484. Thus, we can conclude that digital transformation partially mediates the relationship between technical founders and firm innovation performance and the mediating effect of digital transformation is 15.38%. Therefore, hypotheses H3 and H4 are verified.

Finally, following the Fang et al. (2021) approach, a moderated mediating model is used to further test whether the mediating effects of digital transformation are moderated by VC/PE support. Model (1) in Table 5 confirms a significant positive effect of technical founders on firm innovation performance. Models (2) and (3) reveal that digital transformation plays a mediating role in the above relationships. Next, we test whether VC/PE moderates the relationship between technical founders and innovation performance or the relationship between technical founders and digital transformation. The regression results of model (4) and model (5) show that the interaction term between VC/PE and technical founders are both insignificant.

Meanwhile, The interaction term of VC/PE support and digital transformation in Model (6) and Model (7) has a positive contribution to firm innovation performance (coef.=0.433, $p<0.1$; coef.=0.389, $p<0.1$), and VC/PE support has a moderating effect on the relationship between digital transformation and innovation performance. Specifically, VC/PE support moderates the second half of Technical Founders→Digital Transformation→ Innovation Performance. Therefore, VC/PE support positively moderates the mediating role of digital transformation in the relationship between technical founders and innovation performance. The mediating effect of digital transformation has increased from 15.38 to 29.27%. So, hypothesis H5 is verified.

Robustness checks

To further ensure the validity of the findings, this study performs robustness tests against the above regression results by using alternative dependent variables and mediating variables.

Alternative measures of innovation performance

Considering the potential bias caused by the type of patents on the innovation performance measurement, this paper also uses the number of invention patents of the firm to measure the quality of technological innovation. In addition, the total number of invention, utility model and design patents is employed as a proxy for the quantity of innovation of a firm. The results are shown in models (1) and (3) in Table 6. It can be concluded that the relationship between technical founders and firm innovation remains significantly positive when innovation quality and quantity are considered

Table 4 Results of mediation analysis

Independent variables	Innovation		Digital_1		Innovation
	(1)	(2)	(3)	(4)	(5)
Technical	0.559***	0.484**	0.468**		0.396**
	(0.196)	(0.193)	(0.189)		(0.193)
Academic				-0.533**	
				(0.260)	
Business				-0.422*	
				(0.227)	
Digital_1					0.188**
					(0.074)
Age		0.007	-0.056***	-0.056***	0.018
		(0.013)	(0.013)	(0.013)	(0.014)
Male		1.091**	0.896**	0.891*	0.922**
		(0.461)	(0.453)	(0.454)	(0.459)
Education		-0.057	-0.035	-0.014	-0.050
		(0.108)	(0.106)	(0.120)	(0.106)
Overseas		-0.411*	-0.046	-0.033	-0.402*
		(0.241)	(0.237)	(0.240)	(0.238)
Duality		0.359*	-0.051	-0.047	0.369*
		(0.198)	(0.195)	(0.195)	(0.195)
Asset		0.667***	-0.077	-0.074	0.681***
		(0.137)	(0.134)	(0.135)	(0.135)
LEA		0.145	0.474	0.480	0.056
		(0.664)	(0.651)	(0.653)	(0.655)
ROA		1.461*	0.436	0.435	1.379*
		(0.748)	(0.734)	(0.736)	(0.738)
ONCF		-0.053***	0.019	0.018	-0.057***
		(0.019)	(0.018)	(0.019)	(0.019)
_cons	2.667***	-6.720***	6.366***	6.671***	-7.920***
	(0.126)	(1.899)	(1.864)	(1.929)	(1.929)
N	197	197	197	197	197
R^2	0.040	0.197	0.180	0.181	0.225
F	8.14***	4.57***	4.09***	3.71***	4.87***

Standard errors in parentheses, * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

separately. In addition, model (2) also shows that digital transformation positively and significantly affects the quality of firm innovation. Similarly, model (4) explains a positive and significant relationship between digital transformation and the quantity of firm innovation. Consequently, we can assume that digital transformation plays a partially mediating role in the relationship between technical founders and the quality and quantity of firm innovation. Thus, technical founders not only contribute to the quantity of innovation in firms, but also promote high-quality innovation activities. In summary, hypotheses H1, H3, and H4 are still validated and supported after replacing the dependent variable.

Table 5 Results of moderated mediation analysis

Independent variables	Innovation	Digital_1	Innovation		Digital_1	Innovation	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Technical	0.451**	0.475**	0.357*	0.448**	0.440**		0.319*
	(-0.19)	(-0.19)	(-0.19)	(-0.191)	(-0.19)		(-0.19)
VC/PE	0.981***	-0.203	1.021***	0.995***	-0.011	0.977***	0.947***
	(-0.344)	(-0.344)	(-0.338)	(-0.366)	(-0.364)	(-0.341)	(-0.339)
Digital_1			0.198***			0.222***	0.200***
			(-0.072)			(-0.071)	(-0.072)
Technical× VC/PE				0.092	1.214		
				(-0.769	(-0.765)		
Digital_1× VC/PE						0.433*	0.389*
						(-0.227)	(-0.227)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
_cons	-7.192***	6.464***	-8.472***	-7.220***	6.102***	-8.369***	-8.237***
	(-1.871)	(-1.874)	(-1.897)	(-1.89)	(-1.881)	(-1.90)	(-1.892)
N	197	197	197	197	197	197	197
R^2	0.231	0.182	0.261	0.231	0.193	0.262	0.273
F	5.05***	3.74***	5.42***	4.61***	3.66***	5.43***	5.28***

Standard errors in parentheses, * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table 6 Regression analyses of the robustness test

Independent variables	Innovation Quality		Innovation Quantity		Digital_2	Innovation Performance
	(1)	(2)	(3)	(4)	(5)	(6)
Technical	0.478**	0.372*	0.461**	0.369*	0.455**	0.429**
	(0.191)	(0.190)	(0.197)	(0.197)	(0.208)	(0.194)
Digital_1		0.225***		0.196**		
		(0.072)		(0.075)		
Digital_2						0.121*
						(0.068)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
_cons	-7.009***	-8.442***	-6.144***	-7.388***	6.566***	-7.512***
	(1.884)	(1.899)	(1.940)	(1.970)	(2.049)	(1.940)
N	197	197	197	197	197	197
R^2	0.189	0.229	0.181	0.210	0.236	0.211
F	4.33***	5.00***	4.11***	4.46***	5.75***	4.49***

Standard errors in parentheses, * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Alternative mediating variable

As mentioned in the discussion of variable measurement, we obtained Digitalization_2 by simultaneously collecting the frequencies of words excluding those unrelated to digital transformation strategies, operations and business models. The regression results are illustrated in model (5) in Table 6, and still show a significant positive relationship between technical founders and firm digital transformation

(coef.=0.455, p < 0.05). Model (6) further reveals that digital transformation plays a partially mediating role between technical founders and innovation performance. In summary, hypotheses H2, H3, and H4 are still validated and supported after replacing the mediating variable. Therefore, we may conclude that all the regression results in the above exercises to be stable and reliable.

Endogeneity test

To reduce possible regression bias due to sample self-selection, we further performed an endogeneity test using propensity score matching (PSM). According to Colombo et al. (2022), firm size, founder age, education, and equity concentration are selected as confounding variables. In this paper, the samples are matched 1:4 under the nearest neighbour with replacement. Clearly, after matching, the differences between the control and treatment groups are no longer statistically significant, suggesting that the balancing test is validated. Additionally, the pseudo-R^2 is fairly low and the joint significance test is not rejected before but after matching, which verifies the common support assumption of PSM. Finally, we drop the samples that are off support and the comparative regression analyses of the PSM results in Table 7 show that technical founders still show a robust and significant positive relationship with the innovation performance of Sci-Tech enterprises.

Conclusion and discussion

Conclusion

In this paper, we use 197 annual reports of 124 companies listed on China's STAR Market for 2019–2020 to measure the digital transformation of firms using textual analysis and further investigate its mediating effect on the relationship between technical founders and innovation performance. There are several interesting findings.

First, it is found that technical founder-led firms have shown better innovation performance, not only in terms of innovation quantity, but also in terms of innova-

Table 7 The PSM results

Variables	Innovation Unmatched	Innovation PSM	Innovation Quality Unmatched	Innovation Quality PSM	Innovation Quantity Unmatched	Innovation Quantity PSM
	(1)	(2)	(3)	(4)	(5)	(6)
Technical	0.484**	0.464**	0.478**	0.479**	0.461**	0.435**
	(0.193)	(0.214)	(0.191)	(0.210)	(0.197)	(0.218)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
_cons	-6.720***	-7.308**	-7.009***	-7.378***	-6.144***	-6.834***
	(1.899)	(2.465)	(1.884)	(2.418)	(1.940)	(2.510)
N	197	162	197	162	197	162
R^2	0.197	0.171	0.189	0.167	0.181	0.160
F	4.57***	3.11***	4.33***	3.03***	4.11***	2.87***

Standard errors in parentheses, * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

tion quality. This may be due to the fact that the experience of technical founders promotes the organizational identity of start-ups in innovation activities, enhances the firm's tolerance for failure, and increases its participation in exploratory search strategies that exploit new technology trajectories (Bostan & Mian, 2019). The study by Jiang, Wang and Zeng (2021) confirms the positive impact of the founders' dual role of R&D and management on firm innovation performance. The more the founders of a firm are involved in R&D activities and the higher their centrality in the R&D network, the better the firm's technological innovation performance. This is because high network centrality gives founders a stronger ability to innovate and identify opportunities and attracts their attention to innovation.

Second, founders with different identities have different impacts on the digital transformation of enterprises, specifically in this order technical founder > business founder > academic founder. In SMEs, the influence of certain key individuals may have a greater impact on the direction chosen. This view is a recognition of the centrality of the entrepreneurs and is also consistent with the higher echelon theory on how the managerial characteristics and beliefs of individuals influence the strategic choices of the firm (Barrett et al., 2021). Therefore, the origins of the founders are systematically linked to the technological direction of their newly formed organizations. Technical founder affirms entrepreneurs to engage in behaviors that are consistent with their identity, which in turn further reinforces their technical identity (Zuzul & Tripsas, 2020). That is why, founders contribute to the inertia and flexibility of the firm through the mechanism of identity affirmation, exhibiting different digital transformations.

Finally, digital transformation plays a partially mediating role in the relationship between technical founders and corporate innovation performance. VC/PE support positively moderates the mediating role of digital transformation in the relationship between technical founders and innovation performance. Digital transformation has undoubtedly become a key driver of innovation and has also fundamentally changed profit models and business models. Considering these shifts and the high ambiguities and uncertainties, most academic founders and business founders initially found the adoption of digital ideas challenging, if not completely unattractive. The organizational role identity and organizational domain identity of technical founders interactively explain how companies should respond to digital transformation (Kammerlander et al., 2018). Thus, the image of entrepreneurs and inventors as well as the adoption of new digital processes by leaders contribute to the dynamic capabilities of the company (Ferreira et al., 2019). At the same time, digital transformation requires specific managerial actions of the founders that can help companies to foster and develop new technological innovations (Urbinati et al., 2020).

Theoretical contributions

First, we provide a novel perspective to study the impact of founder identity on firm technological innovation. Importantly, our study reveals the mechanism underlying the influence of technical founders on firm innovation, where firms led by technical founders show optimal innovation performance through digital transformation. This finding extends the literature on technology entrepreneurship and firm innova-

tion, which differs from the previous literature on the impact of internal executive characteristics (Fayolle et al., 2021; Bolzani et al., 2021; Blankesteijn et al., 2021; Ganotakis et al., 2012; Zane, 2022; Reese, Rieger and Engelen, 2021) and external institutional environment (Colino et al., 2014; Seguí-Mas et al., 2018; Hülsbeck & Pickavé, 2014) on firm innovation performance.

Also, our findings suggest that VC/PE support positively moderates the positive effect of digital transformation on firm innovation, thereby enhancing the mediating effect of digital transformation between technical founders and firm innovation performance. Finally, our study enriches the imprinting theory literature by confirming the impact of founder imprinting on identity formation and is also consistent with the higher echelon theory on how individual founder's traits and beliefs influence the firm's strategic decisions (Wei et al., 2018; Wang & Chen, 2020; Pieper et al., 2015; Barrett, Dooley and Bogue, 2021). More broadly, our study highlights the specificity of founder identity and suggests that the recognition of the centrality of entrepreneurs in strategic choices may be crucial to explain innovation performance heterogeneity among Sci-Tech enterprises.

Practical implications

The results of this study have implications for the aim of supporting technology entrepreneurship for technological innovation. The empirical evidence suggests that the strategic choices of Sci-Tech start-ups, such as digital transformation, directly affect firm innovation performance under founder identity heterogeneity. Therefore, national policies should first focus on developing technology entrepreneurship, supporting investment in engineering entrepreneurship education and technology incubation in technology transfer offices, which is especially significant to facilitate the construction of innovative national strategies.

Secondly, strengthening the knowledge diversity of startup teams and bringing in partners with technical backgrounds to participate in technology development and application of nascent companies is an important part of their adaptation to sustainable growth in the digital context. Companies cannot achieve digital transformation and continuous innovation without a co-founder team with complementary capabilities. For technical founders, they have to balance short-term and long-term concerns, keep an eye on changing market dynamics, and make strategic transitions at critical times. In addition to continuously tracking technology frontiers and updating technology reserves, technical founders should also enhance knowledge flow and technology sharing within the organization. For non-technical founders, attracting external high-tech talent to join, not blindly pursuing digital transformation and technology-oriented changes, and leveraging their intellectual strengths and business talents to synergize with organizational changes and business models are the prerequisites for achieving robust growth.

Limitations and future research

This paper measured founder identity only from a single dimension, ignoring the joint effect of multiple founder identities on firms' strategic choices and innovation

performance. In the future, we can further expand the classification criteria of founder identity to reveal the innovation evolution process and the corresponding dominant image of Sci-Tech enterprises in different stages from the perspective of multiple identities. At the same time, it is possible to further track the innovation behavior of firms listed on the STAR Market, especially whether the performance of corporate innovation heterogeneity follows the pre-IPO sequencing after firms with technical founders and academic founders are freed from financing constraints.

Appendix A: founder identity and keywords

Identity	Keywords
Academic Founder	Doctor, Professor, Institute, Science and Technology, Project, Program, Outstanding, Talent, Director, Honor, Committee, Academic, Thesis, Lecturer, Research, Experiment, Laboratory, Standardization, Teacher, Assistant professor, vice president, President, Researcher, Engineering, Physics, Invention, Award, University, Chief, Scientist, Faculty, College, Member, Director, Visiting Scholar, Postdoctoral, Doctor supervisor, PhD., PhD. student, Dean, Vice Dean, Academy of Sciences, Chinese Academy of Sciences, National Natural Science Foundation of China, Journal, Academician, Senior, Academic Leader, Allowance, State Council, Deputy Director, Research Group, Group Leader, Science Fund Leader, Associate Researcher, Monograph
Business Founder	Chief Financial Officer, Financial Personnel, Finance Director, Assistant, Business Administration, Secretary, Market, Marketing, Lawyer, Law, Human Resources, Investment, Advisory, Management, Sales Representative, Manager, Deputy manager, Project Management, Economist, Accountant, Statisticians, Consulting, Planning, Venture, Salesman, Business Managers, Finance, Securities, Funds, Brokers, Audit Department, Investment Banking, Vice President, Director, Statistics, Capital, Supervisor, International Finance, Economics, Consortium Investment, State-owned Investment, Political Economy, Chamber of Commerce, Credit, Account Manager, Resource Management, Trading, President, Trust, Equity, Partner, Copywriter
Technical Founder	Engineering, Science and Technology, Industry, Factory director, Engineers, Testing, Systems and Control, Device, Patent, Participation, Industry Standards, Inspection, Diagnosis System and Standard, R&D, Materials Science, Physics, Technical Director, Material, Natural Science, Data System, Network, Heavy Machinery, Development, Electronic Technology, Partner, Image Processing, Algorithm, System, Coal, Chemical Industry, Energy Sources, Hightech Industries, Data Management, Solutions, Communications, Equipment, Aviation, Machinery, Standardization, Special Allowance, Pharmaceutical, Railways, Bridges, Transportation, Biological, Council, Scientific and Technological Progress, Non-metallic, Ceramic, Process, Quality Inspection, Medical, Experiment, Daily Chemical, Committee, Vice President, Visiting Professor

Appendix B: digital transformation and keywords

Digital Transformation	Keywords
Digital Technologies	Artificial Intelligence (AI), Business Intelligence (BI), Image Understanding, Investment Decision Support System, Intelligent Data Analysis, Intelligent Robots, Machine Learning (ML), Deep Learning, Semantic Search, Biometric Technology, Facial Recognition, Speech Recognition, Identity Verification, Autonomous Driving, Natural Language Processing (NLP)
	Blockchain, Digital Currency, Distributed Computing, Differential Privacy Techniques, Smart Financial Contracts
	Cloud Computing, Stream Computing, Graph Computing, In-Memory Computing, Multi-Party Secure Computing, Neuromorphic Computing, Green Computing, Cognitive Computing, Converged Architecture, Billion-Level Concurrency, EB-Level Storage, Internet of Things (IoT), Cyber-Physical Systems
	Big Data, Data Mining, Text Mining, Data Visualization, Heterogeneous Data, Credit Reporting, Augmented Reality, Mixed Reality, Virtual Reality
Development and Application	Mobile Internet, Industrial Internet, Mobile Interconnection, Internet Healthcare, E-commerce, Mobile Payment, Third-party Payment, NFC Payment, Intelligent Energy, Business-to-Business (B2B), Business-to-Consumer (B2C), Consumer-to-Business (C2B), Consumer-to-Consumer (C2C), Online-to-Offline (O2O), Network Alliance, Smart Wearables, Smart Agriculture, Intelligent Transportation, Intelligent Healthcare, Intelligent Customer Service, Smart Home, Smart Investment, Smart Tourism, Smart Environmental Protection, Smart Grid, Smart Marketing, Digital Marketing, Unmanned Retail, Internet Finance, Digital Finance, Fintech, Financial Technology, Quantitative Finance, Open Banking
Extra Lexicon Based on the BERT Model	Digital Transformation, Digitalization, Information Technology, Digital Technology, Multi-Cloud Environment, Regional Chain, Data Analysis, Digital Economy, Data Model, Digital Strategy, Data Chain, Data-Driven, Underlying Technology, Online Platform, Datafication, Informatization, Networked, Intelligent, Smart, Internet, Automation, Virtualization, Unmanned, Online

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References

Andersson, U., Forsgren, M., & Holm, U. (2002). The strategic impact of external networks: Subsidiary performance and competence development in the multinational corporation. *Strategic management journal*, *23*(11), 979–996.

Baker, M., & Gompers, P. A. (2003). The determinants of board structure at the initial public offering. *The Journal of Law and Economics*, *46*(2), 569–598.

Barrett, G., Dooley, L., & Bogue, J. (2021). Open innovation within high-tech SMEs: A study of the entrepreneurial founder's influence on open innovation practices. *Technovation*, *103*, 102232.

Blankesteijn, M., Bossink, B., & van der Sijde, P. (2021). Science-based entrepreneurship education as a means for university-industry technology transfer. *International Entrepreneurship and Management Journal*, *17*(2), 779–808.

Bolzani, D., Munari, F., Rasmussen, E., & Toschi, L. (2021). Technology transfer offices as providers of science and technology entrepreneurship education. *The Journal of Technology Transfer*, *46*(2), 335–365.

Bostan, I., & Mian, G. M. (2019). Inventor chief executive officers and firm innovation. *International Review of Finance*, *19*(2), 247–286.

Chatterjee, S., Chaudhuri, R., Vrontis, D., & Jabeen, F. (2022). Digital transformation of organization using AI-CRM: From microfoundational perspective with leadership support. *Journal of Business Research*, *153*, 46–58.

Chierici, R., Tortora, D., Del Giudice, M., & Quacquarelli, B. (2021). Strengthening digital collaboration to enhance social innovation capital: An analysis of italian small innovative enterprises. *Journal of Intellectual Capital*, *22*(3), 610–632.

Colino, A., Benito-Osorio, D., & Rueda-Armengot, C. (2014). Entrepreneurship culture, total factor productivity growth and technical progress: Patterns of convergence towards the technological frontier. *Technological Forecasting and Social Change*, *88*, 349–359.

Colombo, M. G., Fisch, C., Momtaz, P. P., & Vismara, S. (2022). The CEO beauty premium: Founder CEO attractiveness and firm valuation in initial coin offerings. *Strategic Entrepreneurship Journal*, *16*(3), 491–521.

Devlin, J., Chang, M. W., Lee, K., & Toutanova, K. (2018). Bert: Pre-training of deep bidirectional transformers for language understanding. arXiv:1810.04805.

Dyer, J. H., & Singh, H. (1998). The relational view: Cooperative strategy and sources of interorganizational competitive advantage. *Academy of management review*, *23*(4), 660–679.

Elia, G., Margherita, A., & Passiante, G. (2020). Digital entrepreneurship ecosystem: How digital technologies and collective intelligence are reshaping the entrepreneurial process. *Technological Forecasting and Social Change*, *150*, 119791.

Fang, G. G., Qalati, S. A., Ostic, D., Shah, S. M. M., & Mirani, M. A. (2021). Effects of entrepreneurial orientation, social media, and innovation capabilities on SME performance in emerging countries: A mediated-moderated model. *Technology Analysis & Strategic Management*, *34*(11), 1326–1338.

Fayolle, A., Lamine, W., Mian, S., & Phan, P. (2021). Effective models of science, technology and engineering entrepreneurship education: Current and future research. *The Journal of Technology Transfer*, *46*(2), 277–287.

Ferrary, M., & Granovetter, M. (2009). The role of venture capital firms in Silicon Valley's complex innovation network. *Economy and society*, *38*(2), 326–359.

Ferreira, J. J., Fernandes, C. I., & Ferreira, F. A. (2019). To be or not to be digital, that is the question: Firm innovation and performance. *Journal of Business research*, *101*, 583–590.

Ganotakis, P. (2012). Founders' human capital and the performance of UK new technology based firms. *Small Business Economics*, *39*(2), 495–515.

Gu, W., & Wang, J. (2022). Research on index construction of sustainable entrepreneurship and its impact on economic growth. *Journal of Business Research*, *142*, 266–276.

Gurbaxani, V., & Dunkle, D. (2019). Gearing up for successful digital transformation. *MIS Quarterly Executive*, *18*(3), 209–220.

Hanoteau, J., & Rosa, J. J. (2019). Information technologies and entrepreneurship. *Managerial and Decision Economics*, *40*(2), 200–212.

Hu, J., Pan, X., & Huang, Q. (2020). Quantity or quality? The impacts of environmental regulation on firms' innovation–quasi-natural experiment based on China's carbon emissions trading pilot. *Technological Forecasting and Social Change*, *158*, 120122.

Hülsbeck, M., & Pickavé, E. N. (2014). Regional knowledge production as determinant of high-technology entrepreneurship: Empirical evidence for Germany. *International entrepreneurship and management journal*, *10*(1), 121–138.

Islam, N., Wang, Q., Marinakis, Y., & Walsh, S. (2022). Family enterprise and technological innovation. *Journal of Business Research*, *147*, 208–221.

Jiang, Y., Wang, D., & Zeng, Q. (2021). Can founders' dual roles facilitate innovation?–from the perspective of founders' R&D network characteristics. *Journal of Business Economics and Management*, *22*(5), 1288–1307.

Kammerlander, N., König, A., & Richards, M. (2018). Why do incumbents respond heterogeneously to disruptive innovations? The interplay of domain identity and role identity. *Journal of Management Studies*, *55*(7), 1122–1165.

Kozanoglu, D. C., & Abedin, B. (2021). Understanding the role of employees in digital transformation: Conceptualization of digital literacy of employees as a multi-dimensional organizational affordance. *Journal of Enterprise Information Management*, *34*(6), 1649–1672.

Lafuente, E., Acs, Z. J., Sanders, M., & Szerb, L. (2020). The global technology frontier: Productivity growth and the relevance of Kirznerian and Schumpeterian entrepreneurship. *Small Business Economics*, *55*(1), 153–178.

Li, R., Rao, J., & Wan, L. (2022). The digital economy, enterprise digital transformation, and enterprise innovation. *Managerial and Decision Economics*, *43*(7), 2637–3256.

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

Lin, Q., & Yi, L. (2022). How digitalisation empowering firm innovation breaks the game? Based on fuzzy set qualitative comparative analysis. *Technology Analysis & Strategic Management*. https://doi.org/10.1080/09537325.2022.2049741

Mackiewicz, M., & Błoch, W. (2022). From skilled engineer to a thriving entrepreneur. On the determinants of successful entrepreneurship in technical sectors.Innovation: The European Journal of Social Science Research,1–21. Doi: 13511610.2022.2034495.

Marvel, M. R., Wolfe, M. T., & Kuratko, D. F. (2020). Escaping the knowledge corridor: How founder human capital and founder coachability impacts product innovation in new ventures. *Journal of Business Venturing*, *35*(6), 106060.

Mimno, D., Wallach, H., Talley, E., Leenders, M., & McCallum, A. (2011, July). Optimizing semantic coherence in topic models. In Proceedings of the 2011 conference on empirical methods in natural language processing (pp. 262–272).

Mosey, S., Guerrero, M., & Greenman, A. (2017). Technology entrepreneurship research opportunities: Insights from across Europe. *The Journal of Technology Transfer*, *42*(1), 1–9.

Muller, D., Judd, C. M., & Yzerbyt, V. Y. (2005). When moderation is mediated and mediation is moderated. *Journal of personality and social psychology*, *89*(6), 852–863.

Nasiri, M., Ukko, J., Saunila, M., & Rantala, T. (2020). Managing the digital supply chain: The role of smart technologies. *Technovation*, *96*, 102121.

Nicolás-Agustín, Á., Jiménez-Jiménez, D., & Maeso-Fernandez, F. (2021). The role of human resource practices in the implementation of digital transformation. *International Journal of Manpower*, *43*(2), 395–410.

Nielsen, K. (2015). Human capital and new venture performance: The industry choice and performance of academic entrepreneurs. *The Journal of Technology Transfer*, *40*(3), 453–474.

Oakey, R. (2012). *High-technology entrepreneurship*. London, United Kingdom: Routledge.

Oppong, G. Y. S., Singh, S., & Kujur, F. (2020). Potential of digital technologies in academic entrepreneurship–a study. *International Journal of Entrepreneurial Behavior & Research*, *26*(7), 1449–1476.

Peng, Y., & Tao, C. (2022). Can digital transformation promote enterprise performance?—From the perspective of public policy and innovation. *Journal of Innovation & Knowledge*, *7*(3), 100198.

Pieper, T. M., Smith, A. D., Kudlats, J., & Astrachan, J. H. (2015). The persistence of multifamily firms: Founder imprinting, simple rules, and monitoring processes. *Entrepreneurship theory and practice*, *39*(6), 1313–1337.

Porfírio, J. A., Carrilho, T., Felício, J. A., & Jardim, J. (2021). Leadership characteristics and digital transformation. *Journal of Business Research*, *124*, 610–619.

Qian, Y., Sun, X., Sun, H., & Yang, J. (2021). Constituent elements, Research Framework and prospects of Agile Organizations in the Digital Age. *R&D Management*, *33*(6), 58–74. https://doi.org/10.13581/j.cnki.rdm.20210280

Reese, D., Rieger, V., & Engelen, A. (2021). Should competencies be broadly shared in new ventures' founding teams? *Strategic Entrepreneurship Journal*, *15*(4), 568–589.
Rippa, P., & Secundo, G. (2019). Digital academic entrepreneurship: The potential of digital technologies on academic entrepreneurship. *Technological Forecasting and Social Change*, *146*, 900–911.
Rodriguez-Lluesma, C., García-Ruiz, P., & Pinto-Garay, J. (2021). The digital transformation of work: A relational view. *Business Ethics the Environment & Responsibility*, *30*(1), 157–167.
Saarikko, T., Westergren, U. H., & Blomquist, T. (2020). Digital transformation: Five recommendations for the digitally conscious firm. *Business Horizons*, *63*(6), 825–839.
Seguí-Mas, E., Oltra, V., Tormo-Carbó, G., & Sarrión-Viñes, F. (2018). Rowing against the wind: How do times of austerity shape academic entrepreneurship in unfriendly environments? *International Entrepreneurship and Management Journal*, *14*(3), 725–766.
Solberg, E., Traavik, L. E., & Wong, S. I. (2020). Digital mindsets: Recognizing and leveraging individual beliefs for digital transformation. *California Management Review*, *62*(4), 105–124.
Sun, L., Liu, S., & Chen, P. (2022). Does the paternalism of founder-managers improve firm innovation? Evidence from chinese non-state-owned listed firms. *Finance Research Letters*, *49*, 103146.
Troise, C., Corvello, V., Ghobadian, A., & O'Regan, N. (2022). How can SMEs successfully navigate VUCA environment: The role of agility in the digital transformation era. *Technological Forecasting and Social Change*, *174*, 121227.
Tsou, H. T., & Chen, J. S. (2022). How does digital technology usage benefit firm performance? Digital transformation strategy and organisational innovation as mediators. *Technology Analysis & Strategic Management*. https://doi.org/10.1080/09537325.2021.1991575
Urbinati, A., Chiaroni, D., Chiesa, V., & Frattini, F. (2020). The role of digital technologies in open innovation processes: An exploratory multiple case study analysis. *R&D Management*, *50*(1), 136–160.
Wang, C., & Hu, Q. (2020). Knowledge sharing in supply chain networks: Effects of collaborative innovation activities and capability on innovation performance. *Technovation*, *94*, 102010.
Wang, S., & Chen, X. (2020). Recognizing CEO personality and its impact on business performance: Mining linguistic cues from social media. *Information & Management*, *57*(5), 103173.
Weber, E., Büttgen, M., & Bartsch, S. (2022). How to take employees on the digital transformation journey: An experimental study on complementary leadership behaviors in managing organizational change. *Journal of Business Research*, *143*, 225–238.
Wei, J., Ouyang, Z., & Chen, H. A. (2018). CEO characteristics and corporate philanthropic giving in an emerging market: The case of China. *Journal of Business Research*, *87*, 1–11.
Wu, F., Hu, H., Lin, H., & Ren, X. (2021). Enterprise digital transformation and capital market performance: Empirical evidence from stock liquidity. *Management World*, *37*(7), 130–144. https://doi.org/10.19744/j.cnki.11-1235/f.2021.0097
Wu, L., Sun, L., Chang, Q., Zhang, D., & Qi, P. (2022). How do digitalization capabilities enable open innovation in manufacturing enterprises? A multiple case study based on resource integration perspective. *Technological Forecasting and Social Change*, *184*, 122019.
Yeganegi, S., Laplume, A. O., & Dass, P. (2021). The role of information availability: A longitudinal analysis of technology entrepreneurship. *Technological Forecasting and Social Change*, *170*, 120910.
Zane, L. J. (2022). Intellectual capital and the acquisition of human capital by technology-based new ventures. *Journal of Intellectual Capital*. https://doi.org/10.1108/JIC-04-2021-0122
Zhang, J., van Gorp, D., & Kievit, H. (2022). Digital technology and national entrepreneurship: An ecosystem perspective. *The Journal of Technology Transfer*. https://doi.org/10.1007/s10961-022-09934-0
Zhao, X., Sun, X., Zhao, L., & Xing, Y. (2022). Can the digital transformation of manufacturing enterprises promote enterprise innovation? *Business Process Management Journal*, *28*(4), 960–982.
Zuzul, T., & Tripsas, M. (2020). Start-up inertia versus flexibility: The role of founder identity in a nascent industry. *Administrative Science Quarterly*, *65*(2), 395–433.

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