

Enhancing Innovation Performance in High-Tech Enterprises: The Interplay of Innovation Policy, Entrepreneurship, and Digital Transformation

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Abstract

This study investigates the intricate relationships between innovation policy, entrepreneurship, and innovation performance in high-tech enterprises, with a particular focus on the mediating role of digital transformation. Utilizing a sample of high-tech enterprises in Hainan, China, and employing structural equation modeling (SEM), the research explores how innovation policy and entrepreneurship drive innovation performance. The results demonstrate that both innovation policy and entrepreneurship significantly enhance innovation performance. Furthermore, digital transformation is found to partially mediate the relationship between these variables, suggesting that it is a crucial mechanism through which innovation policy and entrepreneurship translate into tangible innovation outcomes. The study also highlights the amplifying effect of digital transformation, showing that it enhances the positive impact of innovation policy and entrepreneurship on innovation performance. This underscores the importance of digital transformation as a strategic tool in the digital economy, essential for sustaining competitive advantage. The research makes a valuable contribution to the literature by integrating the concepts of innovation policy, entrepreneurship, and digital transformation into a comprehensive framework and providing empirical evidence of their interplay in the context of high-tech enterprises. The practical implications are significant, indicating that both policymakers and business leaders should prioritize digital transformation initiatives to bolster innovation capabilities and maintain competitive edge in an increasingly digitalized global market. Future research is encouraged to examine the potential moderating effects of organizational culture, market conditions, and technological sophistication on these relationships to further deepen the understanding of innovation dynamics in the digital era.

Keywords: Innovation Policy, Entrepreneurship, Digital Transformation, Innovation Performance

INTRODUCTION

The rapid advancement of technology and the dynamic global environment have positioned innovation as a crucial driver of economic growth, particularly in high-tech industries. High-tech enterprises, often at the forefront of technological progress, play a vital role in sustaining economic development. However, the ability of these enterprises to innovate and maintain competitiveness largely depends on the policies and entrepreneurial activities that support their operations. In the context of Hainan, a region undergoing significant economic transformation, innovation within high-tech enterprises is essential to sustaining future economic growth and ensuring the region's integration into the broader global economy.

Central and local governments in China have recognized the strategic importance of innovation and have implemented various innovation policies designed to overcome market failures that hinder research and development (R&D) processes in these enterprises. These policies aim to create an environment conducive to innovation, thereby increasing the likelihood of successful innovation outcomes (Ito et al., 2017). Innovation policies in China have evolved to address the complex needs of high-tech enterprises, ranging from direct financial support and tax incentives to fostering a collaborative ecosystem that encourages knowledge sharing and technological advancement (Li & Peng, 2022).

Innovation, inherently a high-risk activity, offers the potential for high returns, but its success is contingent upon a favorable policy environment and the ability of enterprises to adapt and respond to new opportunities.

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The effectiveness of innovation policies varies depending on the specific innovation environment in which high-tech enterprises operate (Zhang et al., 2019). Different innovation policies can lead to diverse innovation outcomes, ultimately influencing the overall innovation performance of an enterprise (Zhou et al., 2017). Moreover, the dynamic nature of innovation processes necessitates continuous policy adjustments to align with the evolving technological landscape and market demands.

In addition to innovation policies, entrepreneurship plays a pivotal role in fostering innovation within high-tech enterprises. Entrepreneurship, characterized by the willingness to take risks, the drive for innovation, and a pioneering spirit, has reached unprecedented levels of importance in the context of China's economic development (Peng et al., 2022). Entrepreneurs are increasingly seen as catalysts for innovation, driving the development of new products, services, and business models that can transform industries and markets. As emphasized by General Secretary Xi Jinping, entrepreneurs are expected to be the explorers, organizers, and leaders of innovation and development. They must courageously promote innovations in production technology and market strategies. Understanding the relationship between entrepreneurship and innovation in high-tech enterprises is therefore critical to stimulating entrepreneurial spirit and achieving continuous innovation.

The current global landscape is marked by unprecedented changes, posing severe challenges to China's economic development. The rise of the digital economy, driven by rapid advancements in digital technologies, has introduced new opportunities and challenges for high-tech enterprises. In response to these challenges, the Chinese government has introduced a series of innovation policies and digital transformation strategies aimed at encouraging enterprises to adopt digitalization as a means of sustaining innovation performance (Chen & Qiu, 2022). The adoption of new-generation digital technologies, such as artificial intelligence, big data, and the Internet of Things (IoT), is reshaping resource allocation and the organizational boundaries of innovation in high-tech enterprises, leading to sustainable improvements in their innovation performance (Wang, 2021).

Digital transformation represents not just a technological shift but a fundamental rethinking of how businesses operate and create value. For high-tech enterprises, digital transformation is a strategic imperative that can enhance innovation capabilities, improve operational efficiency, and unlock new market opportunities. However, the successful implementation of digital transformation requires strong leadership, a supportive organizational culture, and a clear vision of how digital technologies can be integrated into the business strategy.

In light of these factors, this paper seeks to construct a comprehensive model that examines the relationships between innovation policy, entrepreneurship, digital transformation, and innovation performance. By conducting an empirical analysis using a sample of high-tech enterprises in Hainan, this study aims to elucidate the mechanisms through which innovation policy and entrepreneurship influence innovation performance in the digital economy era. The findings are intended to provide a theoretical foundation and practical guidance for enhancing the innovative capabilities of high-tech enterprises in Hainan, contributing to the region's economic resilience and long-term growth.

LITERATURE REVIEW

Innovation Performance

The concept of innovation performance has evolved as innovation activities have increasingly become critical for the survival and development of enterprises. Scholars have varying definitions of innovation performance, with most agreeing that it reflects the efficiency of inputs and outputs in innovation activities and the resulting impact on a company's operations. Hagedoorn and Cloudt (2003) categorize innovation performance into narrow and broad definitions, where the former refers to the level of innovation within enterprises and the latter encompasses the broader outcomes of innovation. Similarly, Yu, Liu, and Zhao (2023) emphasize that innovation performance is a measure of the value increase realized through new technologies. Therefore, this study considers innovation performance as closely tied to both the process and outcomes of enterprise innovation, serving as a crucial indicator of the efficiency and success of these activities. Based on this understanding, the study hypothesizes:

H1: Innovation policy positively influences enterprise innovation performance.

The evaluation of innovation performance must consider both the process and results of innovation activities. Scholars like Christensen (1995) and Gao et al. (2004) argue for a comprehensive approach, where innovation performance is divided into innovation output performance and innovation process performance. Chen and Chen (2006) also support this view by dividing high-tech enterprises' innovation performance into these two categories. This study follows this approach, evaluating the innovation performance of Hainan's high-tech enterprises through both innovation output performance (IOP) and innovation process performance (IPP), each measured by five items.

Innovation Policy

Innovation policy represents the government's deliberate efforts to support innovation activities, encompassing a variety of direct and indirect measures. Chen (2013) defines innovation policy as a system integrating science and technology policy, economic policy, and industrial policy, aimed at creating a conducive environment for innovation. Rothwell et al. (2009) classify innovation policies into three categories: supply-type, demand-type, and environment-type policies, a classification further expanded by Liu et al. (2018) to include strategic and evaluation policies. This paper adopts the classification proposed by Peng et al. (2008) and others, dividing innovation policy into supply-type, demand-type, and environment-type categories, with each category containing several measurement items.

Innovation policy is recognized as an evolving concept that adapts to changes in social practice, characterized by complexity and context-dependence. Li et al. (2022) suggests that any policy aimed at fostering innovation can be considered an innovation policy, including management services, tax incentives, and financial support. The classification method employed in this study is widely accepted in both domestic and international research, allowing for a systematic and comprehensive analysis of innovation policies and their impact on enterprise innovation performance. In line with this, the study hypothesizes:

H2: Innovation policy has a positive impact on digital transformation.

Entrepreneurship

Entrepreneurship is a multifaceted concept with various interpretations depending on the context. Schumpeter (2012) views entrepreneurship as the essence of economic innovation, driven by the entrepreneurial spirit. Hornsby et al. (2002) emphasize the role of entrepreneurship in revitalizing enterprises and enhancing their innovative capabilities. More recently, Hu et al. (2020) and Cheng and Xu (2022) have expanded the definition to include aspects such as patriotism, social responsibility, and international vision. This study defines entrepreneurship as a series of forward-looking activities driven by innovation, risk-taking, and pioneering ideologies, essential for strategic renewal and enterprise growth.

Scholars agree that entrepreneurship is composed of multiple dimensions, with innovation, risk-taking, and pioneering being the most commonly cited. Miller et al. (1983) and Covin and Slevin (1991) both highlight these dimensions in their definitions of entrepreneurship. This paper adopts these three dimensions—innovation (INN), risk-taking (RIT), and pioneering (PIO)—as the core components of entrepreneurship, drawing on scales developed by Covin and Slevin (1991) and validated by subsequent research. Based on these insights, the study hypothesizes:

H3: Entrepreneurship positively affects corporate innovation performance.

H4: Entrepreneurship positively influences digital transformation.

Digital Transformation

Digital transformation represents a higher level of change compared to data conversion and digital upgrading, involving a fundamental shift in how enterprises operate. Ebert and Duarte (2018) describe digital transformation as a process where digital technologies are applied to enhance organizational efficiency and automation. Ilvonen et al. (2018) and Vial (2019) further argue that digital transformation triggers significant changes in enterprise operations, leading to new business models and enhanced innovation performance. This

study defines digital transformation as the process of upgrading an enterprise's organizational design, business model, and processes through technology, with the goal of achieving a competitive advantage and improved performance.

While there is no unified standard for measuring digital transformation, several frameworks have been proposed. Matt et al. (2015) suggest four dimensions: technology use, value creation, structural change, and financial support. Hess et al. (2016) build on this by providing strategic questions to guide digital transformation efforts. Wang et al. (2020) further refine these dimensions, focusing on digital technology use, value creation, and structural change. This study adopts these dimensions to evaluate digital transformation in high-tech enterprises, using the scale developed by Hess et al. (2016) and modified by Wang et al. (2020). To explore the impact of digital transformation, the study hypothesizes:

H5: Digital transformation positively affects enterprise innovation performance.

Mediating Role of Digital Transformation

Digital transformation is posited to mediate the relationship between innovation policy and innovation performance. As China's digital economy continues to grow, the "real economy + digitalization" model has become essential for enterprises aiming to achieve high-quality development. Government support for digital transformation, through policies like subsidies and tax incentives, encourages high-tech enterprises to invest in R&D and enhance their innovation capabilities. In light of this, the study hypothesizes:

H6: Digital transformation mediates the relationship between innovation policy and innovation performance.

Digital transformation also mediates the relationship between entrepreneurship and innovation performance. Entrepreneurs who embrace digital technologies can fundamentally change their enterprises' R&D and production methods, leading to continuous innovation and new competitive advantages. Thus, the study hypothesizes:

H7: Digital transformation mediates the relationship between entrepreneurship and innovation performance.

METHOD

Participants

The participants of this study were selected using stratified random sampling, focusing on middle and senior managers from high-tech enterprises across 20 cities and counties in Hainan Province, China. The target population initially included 2,096 enterprises, with a particular emphasis on Haikou and Sanya cities, which together account for over 64% of the high-tech sector in the region. Stratified random sampling was employed to ensure that the sample accurately reflected the diversity of the high-tech sector across different geographic areas and enterprise sizes.

Using Rao's software for sample size determination, the minimum required sample size was calculated to be 377 at a 95% confidence level with a 5% margin of error. To accommodate potential non-responses, the sample size was increased by 20%, resulting in a target of 453 distributed questionnaires.

Data collection was conducted over three months, and after excluding incomplete or low-quality responses, 382 valid questionnaires were obtained, yielding a response rate of 84.33%. The sample predominantly consisted of participants aged 31-50 years (89.27%), representing the experienced management demographic within the high-tech industry in the region.

Measures

This study employed a structured questionnaire to measure the constructs of innovation policy, entrepreneurship, digital transformation, and innovation performance. All constructs were measured using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

The innovation policy construct was measured using three dimensions: supply-type, demand-type, and environment-type policies. The items for this construct were adapted from the scale developed by Liu et al.

(2018) and Peng et al. (2008), which are widely recognized in the literature for assessing innovation policy impacts. The Item-Content Validity Index (I-CVI) for this measure ranged from .75 to .88, and the Scale-Content Validity Index (S-CVI) was .83, indicating good content validity. The Cronbach's Alpha for this scale was .927, and the Composite Reliability (CR) was .930, with an Average Variance Extracted (AVE) of .552, ensuring reliability and convergent validity.

Entrepreneurship was assessed across three dimensions: innovation (INN), risk-taking (RIT), and pioneering (PIO). The scale for measuring entrepreneurship was adapted from the work of Covin and Slevin (1991) and later validated by Miller and Friesen (1983). These scales are well-established in the entrepreneurship literature and have been used in numerous studies to measure entrepreneurial orientation. The I-CVI for entrepreneurship items ranged from .78 to .86, with an S-CVI of .85. The reliability indices included a Cronbach's Alpha of .920, CR of .920, and an AVE of .610, indicating strong internal consistency and validity.

The digital transformation construct was measured using four dimensions: technology use, value creation, structural change, and financial support. This scale was adapted from the frameworks proposed by Matt et al. (2015) and Hess et al. (2016), which provide a comprehensive approach to evaluating digital transformation in enterprises. The I-CVI values for this measure were between .76 and .88, and the S-CVI was .84. The scale exhibited a Cronbach's Alpha of .897, CR of .898, and an AVE of .550, confirming its reliability and validity.

Innovation performance was measured through two dimensions: innovation output performance (IOP) and innovation process performance (IPP). The items were adapted from the works of Christensen (1995) and Gao et al. (2004), which have been instrumental in measuring innovation performance in high-tech enterprises. The I-CVI for the innovation performance items ranged from .80 to .89, and the S-CVI was .87. The reliability indices for this measure were a Cronbach's Alpha of .935, CR of .935, and an AVE of .631, indicating excellent reliability and validity.

Data Analysis

The data analysis involved multiple steps, starting with descriptive statistics to understand the characteristics of the sample. Reliability and validity analyses were conducted using Cronbach's Alpha, Composite Reliability (CR), and Average Variance Extracted (AVE) to ensure the robustness of the measures. The structural equation modeling (SEM) technique was employed to test the hypothesized relationships between the constructs. Predictive relevance of the model was assessed using the Q^2 statistic, with values above .5 indicating strong predictive capability. The model fit was evaluated using the Standardized Root Mean Square Residual (SRMR), with a value below .1 considered indicative of good fit.

The study also examined the mediating effects of digital transformation using the variance accounted for (VAF) approach. Bootstrapping with 5,000 samples was used to test the significance of the direct and indirect effects. The effect sizes were interpreted based on Cohen's guidelines, with values of .02, .15, and .35 representing small, medium, and large effects, respectively.

RESULTS

Measurement Model

To ensure the reliability and validity of the constructs used in this study, the measurement model was assessed through confirmatory factor analysis (CFA). The evaluation of the first-order and second-order constructs focused on internal consistency, convergent validity, and discriminant validity.

Internal consistency was measured using Cronbach's Alpha and Composite Reliability (CR). All constructs showed Cronbach's Alpha values above the threshold of .7, indicating good internal consistency. Similarly, CR values exceeded .7 for all constructs, further supporting the reliability of the scales. The Average Variance Extracted (AVE) for each construct was also above the acceptable threshold of .5, indicating that the items within each construct captured the intended latent variables effectively.

Table 1 Measuremnt Model

Construct	Dimension	Items	λ	α	CR	AVE			
Innovation Policy	Supply-Oriented Policy	SOP1	.805	.892	.908	.632			
		SOP2	.789						
		SOP3	.762						
	Demand-Oriented Policy	DOP1	.844				.903	.921	.674
		DOP2	.823						
		DOP3	.819						
	Environment-Oriented Policy	EOP1	.768				.876	.890	.623
		EOP2	.787						
		EOP3	.799						
Entrepreneurship	Innovativeness	INN1	.831	.908	.921	.656			
		INN2	.844						
		INN3	.813						
	Risk-Taking	RIT1	.821				.897	.910	.657
		RIT2	.810						
		RIT3	.833						
	Pioneering	PIO1	.826				.912	.925	.674
		PIO2	.845						
		PIO3	.818						
Digital Transformation	Technology Use	TCH1	.849	.890	.904	.648			
		TCH2	.832						
		TCH3	.818						
Innovation Performance	Innovation Output	IOP1	.869	.924	.935	.701			
		IOP2	.853						
		IOP3	.832						
	Innovation Process	IPP1	.822				.901	.914	.656
		IPP2	.810						
		IPP3	.807						

Structural Model

The structural model was tested to evaluate the hypothesized relationships between innovation policy, entrepreneurship, digital transformation, and innovation performance. The model’s predictive relevance was assessed using the Q² statistic, with values indicating substantial predictive capability for the constructs. The Q² values for digital transformation and innovation performance were .881 and .833, respectively, signifying that the model has strong predictive relevance.

The effect sizes (f²) of the exogenous latent variables were also calculated to assess their impact on the endogenous variables. Digital transformation had the largest effect size (f² = .320) on innovation performance, while the effects of innovation policy and entrepreneurship on innovation performance were smaller but still significant (f² = .075 and .045, respectively).

The overall fit of the structural equation model was evaluated using the Standardized Root Mean Square Residual (SRMR), which yielded a value of .064, indicating a good fit between the model and the observed data. The model also showed no signs of common method bias, and the conditions for content, discriminant, and convergent validity were satisfied, allowing for the use of confirmatory factor analysis.

The direct effects of the hypothesized relationships were tested using SmartPLS 4.0 with a bootstrapping procedure set at 5,000 samples. The results supported the significance of the paths from innovation policy to innovation performance ($\beta = .272, t = 4.100, p < .001$), entrepreneurship to innovation performance ($\beta = .194, t = 2.751, p < .01$), and digital transformation to innovation performance ($\beta = .492, t = 8.104, p < .001$).

The mediating role of digital transformation was examined using the variance accounted for (VAF) method. The results indicated that digital transformation partially mediated the relationship between innovation policy and innovation performance (VAF = 34.77%) and between entrepreneurship and innovation performance (VAF = 55.50%). These findings suggest that digital transformation is a significant mediator, enhancing the impact of both innovation policy and entrepreneurship on innovation performance.

Table 2 Structural Model

Path	β	SE	t	p	R ²	f ²
Innovation Policy → Innovation Performance	.272	.066	4.100	.000	.583	.075
Entrepreneurship → Innovation Performance	.194	.070	2.751	.006	.583	.045
Digital Transformation → Innovation Performance	.492	.061	8.104	.000	.583	.320
Innovation Policy → Digital Transformation	.353	.058	6.086	.000	.637	.217
Entrepreneurship → Digital Transformation	.411	.063	6.524	.000	.637	.268

DISCUSSION

The results of this study provide substantial evidence that innovation policy and entrepreneurship significantly impact the innovation performance of high-tech enterprises in Hainan, China, with digital transformation playing a pivotal mediating role. The positive relationship between innovation policy and innovation performance (H1) underscores the importance of government interventions in fostering an innovation-friendly environment. This finding aligns with previous research suggesting that well-designed innovation policies can effectively stimulate R&D activities and promote technological advancements within enterprises (Chen & Qiu, 2022; Zhang et al., 2019).

Entrepreneurship, characterized by innovation, risk-taking, and pioneering, was also found to positively influence innovation performance (H3). This result supports the view that entrepreneurial activities drive firms toward continuous innovation, which is essential for maintaining competitive advantages in rapidly changing markets (Schumpeter, 2012; Hu et al., 2020). Additionally, the significant impact of entrepreneurship on digital transformation (H4) highlights the role of entrepreneurs in leading digital initiatives within firms, further enhancing their innovation capabilities (Wang et al., 2020).

The study also confirms the hypothesized positive relationship between digital transformation and innovation performance (H5). Digital transformation, which involves the integration of digital technologies into business processes, was shown to significantly improve both innovation output and process performance. This is consistent with the notion that digitalization enhances organizational efficiency and fosters the development of new products and services (Ebert & Duarte, 2018; Vial, 2019).

The mediating role of digital transformation between innovation policy and innovation performance (H6), as well as between entrepreneurship and innovation performance (H7), provides new insights into how digitalization can amplify the effects of these factors on firm performance. The mediation analysis indicates that digital transformation is a crucial mechanism through which innovation policies and entrepreneurial activities translate into improved innovation outcomes, reinforcing the idea that digital capabilities are essential for modern enterprises to thrive in the digital economy (Yu et al., 2023).

The findings of this study are consistent with and extend the existing literature on innovation and digital transformation. Previous research has highlighted the importance of innovation policies in promoting technological development (Chen & Qiu, 2022) and the role of entrepreneurship in driving firm innovation (Schumpeter, 2012). However, this study adds to the literature by explicitly examining the mediating role of digital transformation, which has been relatively underexplored in the context of high-tech enterprises in China (Wen et al., 2023).

Moreover, while past studies have often focused on the direct effects of innovation policies and entrepreneurship on firm performance, this research emphasizes the importance of digital transformation as a mediating factor. This approach provides a more nuanced understanding of the pathways through which these variables influence innovation outcomes, offering valuable insights for both scholars and practitioners (Hornsby

et al., 2002).

Theoretical and Practical Implications

Theoretically, this study contributes to the literature on innovation management by integrating the concepts of innovation policy, entrepreneurship, and digital transformation into a single framework. The findings suggest that digital transformation is not merely a technological upgrade but a strategic tool that enhances the effectiveness of innovation policies and entrepreneurial efforts. This has implications for future research, which should continue to explore the interplay between these factors in different contexts (Li et al., 2022).

Practically, the results offer important lessons for policymakers and business leaders. For policymakers, the study highlights the need to design innovation policies that not only encourage R&D but also support digital transformation initiatives within firms. For business leaders, the findings underscore the importance of embracing digital technologies and fostering an entrepreneurial culture to enhance innovation performance. By doing so, firms can better navigate the challenges of the digital economy and maintain their competitive edge (Vial, 2019; Wang et al., 2020).

Limitations and Future Research

Despite its contributions, this study has several limitations that should be acknowledged. First, the research is based on a sample of high-tech enterprises in Hainan, which may limit the generalizability of the findings to other regions or industries. Future research could replicate this study in different contexts to validate the results and explore potential variations (Gao et al., 2004).

Second, the study relies on self-reported data, which may be subject to common method bias. Although steps were taken to minimize this risk, future research could benefit from using objective measures of innovation performance and digital transformation (Fornell & Larcker, 1981).

Finally, while the study examines the mediating role of digital transformation, it does not explore potential moderating factors that could influence the strength of the relationships between the variables. Future research could investigate the role of factors such as organizational culture, market conditions, or the level of technological sophistication in shaping the impact of innovation policies and entrepreneurship on firm performance (Chen et al., 2006).

CONCLUSION

In conclusion, this study provides strong evidence that innovation policy, entrepreneurship, and digital transformation are key drivers of innovation performance in high-tech enterprises. By highlighting the mediating role of digital transformation, the research offers new insights into how firms can enhance their innovation capabilities in the digital economy. These findings have important implications for both theory and practice, suggesting that a holistic approach that integrates policy support, entrepreneurial activities, and digitalization is essential for achieving sustained innovation and competitive advantage (Verhoef et al., 2021; Wang et al., 2022).

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