

A Study on the Impact of Digital Competence, Teamwork on Service Innovation Performance: Moderating Effect Based on Open Innovation

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Abstract: This research primarily focuses on evaluating the impact of digital literacy on the innovation performance of service in intelligent manufacturing enterprises. It analyzes the mediating role of teamwork and explores the moderating effect of open innovation. With technology increasingly permeating every aspect of enterprise operations, organizations are undergoing a significant wave of digitization. Concurrently, teamwork has become a core factor in driving organizational performance, while open innovation, as a novel mode of knowledge flow and collaboration, plays an increasingly important role in contemporary business management. This paper seeks to construct a theoretical model to reveal how digital literacy influences service innovation in enterprises, and how digital literacy, teamwork, and open innovation collectively enhance the performance of service innovation. By collecting representative data from intelligent manufacturing enterprises and employing empirical analysis methods, this study particularly emphasizes the mediating role of teamwork and the potential moderating effect of open innovation. The analysis results indicate a positive correlation between digital literacy and service innovation performance, further demonstrating that effective teamwork and proactive open innovation significantly promote innovation performance in organizations. Additionally, teamwork mediates between digital literacy and service innovation performance, whereby differences in educational backgrounds and personal knowledge among team members, as well as communication exchanges within social networks, effectively contribute to organizational innovation performance. Open innovation underscores the importance of attitudes towards internal and external collaboration in leveraging digital technology to drive service innovation. These research findings are crucial for understanding how modern intelligent manufacturing enterprises can enhance their innovation capabilities through digital technology, teamwork, and internal and external cooperation.

Keywords: Digital capabilities; Teamwork; Service innovation performance; Open innovation

1. Introduction

In the current business environment, digital transformation has become a key driver for enterprises to enhance competitiveness and achieve innovative development. With the pace of technological advancement, companies must gradually adjust their strategies in order to maintain a leading position in the digital age. In recent years, as the importance of collaboration mechanisms has been increasingly recognized, there has been a growing body of research on the impact of team collaboration on corporate performance. How to leverage the positive effects of team collaboration to improve corporate performance has become a very meaningful topic. At the same time, innovation has transcended the boundaries of traditional closed R&D, giving rise to the concept of open innovation, which encourages companies to break internal thinking barriers and actively embrace external intellectual resources and creativity. However, the specific impact of digital capabilities, team collaboration, and open innovation on service innovation performance remains a focal point of attention for both academia and industry. This study aims to deepen the understanding of the essence of digital capabilities, analyze methods to stimulate effective team collaboration, as well as the motivations and practices of open innovation, and explore their impact on service innovation performance. The aim of this study is to provide an integrated perspective that offers new strategic pathways for companies to achieve service innovation performance. By systematically analyzing existing literature, constructing theoretical models, and utilizing empirical data for validation, this paper hopes to provide both theoretical and practical guidance for companies in the process of digital and innovation transformations.

2. Literature Review

2.1. Digital competence

2.1.1. Connotation of digital competence

The essence of digital capabilities has gained increasing attention from scholars in recent years, in light of the booming development of digital technologies such as big data, machine learning, artificial intelligence, the Internet of Things, cloud computing, and blockchain. In the field of management and entrepreneurship research, digital capability is identified as a key element for organizations to obtain sustainable competitive advantages in the digital era (Ross et al., 1996; Zhuang et al., 2020). Digital capability is a dynamic digital ability of organizations to swiftly adopt responsive strategies in response to environmental changes, which is crucial for the survival and development of new start-ups as well as the transformation of traditional enterprises (Zhu et al., 2020; Ferreira et al., 2020; Levallet and Chan, 2018). The theoretical development of digital capabilities is not merely theoretical speculation, as its essence and concept stem from scholars' studies on enterprises' information technology capabilities and dynamic abilities.

From a scholarly perspective, this study explains digital capability as a comprehensive process in which organizations strategically deploy digital technologies and tools to identify value creation points, enhance customer experiences, improve production efficiency, and systematically restructure business models. Undertaking digital transformation entails disrupting traditional operational methods, prompting enterprises to reassess market demands, stimulate internal innovation potentials, and establish a more flexible, interconnected, and transparent business environment. It encompasses not only technological upgrades, but also cultural mindset shifts and strategic realignments. Enterprises must ensure that their transformation measures align with market dynamics and effectively address evolving consumer demands.

Focusing on enhancing user experiences, the objective is to elevate customer engagement and satisfaction through digital means, which has become a pivotal aspect of the transformation process. Meanwhile, enterprises also strive to optimize production and operational processes through automation and data analysis to boost efficiency and reduce costs. All these endeavors converge

towards a central goal: reshaping operational frameworks to achieve sustainable innovation in business models. It is worth noting that businesses that adjust their business models, cultural ambiance, organizational structures, and internal/external network relationships in accordance with digital trends can establish a firm footing in market competition. This fully embodies the significant importance of digital capabilities. Through this holistic transformation, enterprises embark on a new chapter of innovation and efficient operations.

2.1.2. There are many mechanisms for the impact of digital capabilities in the digital economy that are unknown to us

In recent years, with the development and application of emerging digital technologies represented by "cloud, big, material, intelligence, and mobility", the digitalization of manufacturing industry and servitization have shown a deep fusion development trend, which has prompted the servitization to move forward to its advanced stage - digital servitization. Digital technology has significantly impacted economic activity, affecting consumer behavior, entrepreneurial behavior, and government policy-making (Goldfarb, A., 2015). Digital capability positively impacts manufacturing company performance through digital innovation and value co-creation within and outside the company (Xiaoli Wang, 2022). Digital capabilities, such as sensing, responsiveness, process scanning, and ecosystem connectivity, enhance operational excellence, revenue growth, and customer and stakeholder relationships in digital businesses (Junior, J.&Maçada, A.,2020).

In summary, digital capability has gradually received more and more attention from scholars, and thanks to the rapid development of digital capability-related research and theory, the concept and connotation of digital capability have been continuously enriched, and relevant theoretical and empirical research has made significant progress. However, although the importance of digital capability has become increasingly prominent in service innovation practice, its theoretical research started late, and relevant empirical studies are still relatively scarce and scattered, which leads to many unknown mechanisms of the impact of digital capability in the era of digital economy.

2.2. Service innovation performance

2.2.1. Connotation of open innovation

The definition of the concept of service innovation needs to be based on the understanding of the concept of innovation. Schumpeter argues that innovation consists of two aspects: one is the reorganization of elements through the reorganization of owned resources; the other is the renewal of elements through the absorption of completely new resources (Schumpeter & Swedberg, 2021). Tidd argues that innovation is the process by which a firm improves or redevelops the design of its products and services in order to survive and grow (Tidd & Hull, 2003). Gallouj argues that innovation does not necessarily involve the application of new technologies or the production of new products, but can be manifested in the form of giving new value to a product or providing a unique service experience (Gallouj & Weinstein, 1997). By interpreting the concept of innovation and combining it with the characteristics of services, scholars have proposed an understanding of the connotation of service innovation from the different perspectives of their respective studies.

This has triggered a wave of service-oriented transformation of manufacturing globally, where manufacturing firms are beginning to seek ways to achieve value co-creation with customers as the starting point (Szász, Demeter, Boer, & Cheng, 2017). Customers, as value co-creators and value builders, play an important role in value formation, such as intellectual support, value integration, and value innovation, and using knowledge and information to serve customers is an effective strategy for servitization in manufacturing (Cheng & Krumwiede, 2017). Customers are both the starting point and the end point of service innovation, and the degree and manner of customer participation directly affects the performance of service innovation (Feng Wenna & Liu. Ruyue, 2021). Scholars at home and abroad regard the service innovation behavior of the manufacturing industry as the servicization

of the manufacturing industry, and point out that there are three reasons why the manufacturing industry adopts the strategy of servicization: setting up competitive barriers, locking up customers, and improving the level of differentiation (Gremyr, Witell, Löfberg, Edvardsson, & Fundin, 2014). Relying solely on technological innovation is not able to maintain the competitive advantage of manufacturing differentiation, so service innovation and service business upgrading is a strategic countermeasure for the manufacturing industry facing the industry's move towards maturity, and it is also a key strategy for overcoming and getting rid of the trap of productization (C Kowalkowski, H Gebauer, & R. Oliva, 2017).

2.2.2. Service innovation is the new force driving organizational innovation

Adopting service design in organizations leads to significant changes in mindset and routines, transforming the organization's innovation capability and influencing its adoption (Kurtmollaiev, S., Fjuk, A., Pedersen, P., Clatworthy, S., & Kvåle, K., 2018). Three archetypes of open service innovation have been identified: internal group development, satellite team development, and rocket team development, which can guide firms in organizing for both incremental and radical service innovations (Myhrén, P., Witell, L., Gustafsson, A., & Gebauer, H., 2017). Innovation orientation, external partner collaboration, and information technology capability significantly contribute to service delivery innovation, which in turn improves firm performance (Chen, J., 2009).

In summary, service innovation, as a new driving force for organizational innovation, is reflected in the fact that it expands the focus of innovation to the development, delivery and experience of services, emphasizes customer centricity and cross-boundary cooperation, and opens up new paths of innovation through the use of digital technology. This not only expands the dimensions of organizational innovation and enhances sensitivity to and satisfaction of customer needs, but also promotes knowledge sharing and the construction of ecosystems, which ultimately strengthens the market competitiveness and sustainability of organizations.

2.3. Teamwork

2.3.1 The meaning of teamwork

Service R&D team structure influences the relationship between IT processes and Product-Service Innovation, with autonomous teams favoring customer-based processes and formalized teams favoring logistics-based processes (Ferran Vendrell-Herrero, 2020). Team learning capability, consisting of relationship learning, trusting team climate, and employee commitment, strongly positively impacts innovation ambidexterity in professional service firms (V. H. Batt-Rawden, 2019). Team dynamics and organizational learning positively influence organizational innovativeness, leading to better product and service development (Ikramul Hasan, 2020). Pair collaboration fosters innovative thinking, alignment, and engagement, offering a promising intermediate step towards teamwork in organizations (Paola Bellis, R. Verganti, 2019).

2.3.2. Team integration is a new trend within organizations

Organizational culture and teamwork research is expanding, with a focus on knowledge management, patient safety culture, knowledge exchange, interprofessional collaboration, and innovation (Humberto Iván Morales-Huamán, 2023). Effective teamwork, characterized by cooperation, communication, coordination, conflict management, coaching, and shared cognition, leads to greater team performance gains and recursive feedback loops that guide future performance (Bisbey, T. & Salas, E., 2019). Organizations must create a collaborative team culture to effectively compete in the global economy, focusing on co-sharing responsibility and acting as a global team of committed individuals (C. Lele, 2019).

In summary, team integration, as a new trend within organizations, highlights the importance of cross-functional cooperation, shared goals, information and resource sharing, and aims to enhance

decision-making quality and innovation by breaking down departmental barriers and promoting knowledge exchange and cultural integration. This integration trend reflects the need of modern organizations to adapt to rapidly changing market environments and respond to complex challenges, enhancing organizational flexibility, efficiency and competitiveness by building a cohesive working whole.

2.4. Open Innovation

2.4.1. Connotation of open innovation

Scholars such as Li Wenyuan have elaborated on open innovation from a technical perspective, dividing it into two parts: technology acquisition and technology utilization. Technology acquisition refers to obtaining necessary new knowledge or new technologies through cooperation and communication with external forces, such as outsourcing and intellectual property licensing. On the other hand, technology utilization focuses more on the subsequent development of these technologies and knowledge, including how to transform technological achievements into commercial products or services to realize market value (Deng et al., 2011). Additionally, scholars like Peng Zhenglong classify open innovation into three modes based on the flow of innovation: external driver mode, internal driver mode, and bidirectional interactive mode. The external driver mode involves introducing external innovative results into the company, while the internal driver mode entails promoting internal innovative results to external markets. The bidirectional interactive mode integrates both, reflecting a more complex and dynamic mode of open innovation interaction (Ren & Gao, 2020).

From a macro perspective, open innovation transcends traditional organizational boundaries, encouraging breakthrough thinking to seek innovation possibilities from a broader viewpoint. This approach advocates the sharing and collaboration of internal and external resources, enabling companies to leverage a more diverse range of resources and capabilities to achieve a more flexible and efficient innovation process. This interactive exchange not only accelerates the development and application of new technologies but also brings more abundant business opportunities to companies, enabling them to maintain a leading position in fierce market competition. In conclusion, open innovation embodies a modern innovation strategy that transcends barriers, co-creates, and shares value, serving as an important means for enterprises to effectively respond to the increasingly complex economic environment and market changes.

2.4.2. Open innovation emphasizes accelerating the innovation process through collaboration and knowledge exchange beyond organizational boundaries

Open innovation 4.0 can enhance sustainable innovation ecosystems and boost the digital transition by promoting smart and responsible innovation cycles through knowledge flows and green governance (Joana Costa, J. Matias, 2020). Business accelerators play a critical role in developing entrepreneurial support ecosystems by harnessing open innovation, increasing capacity and embedding them within a global innovation system (Aleš Pustovrh, 2020). Open innovation, not just technology, is at the heart of digital transformation, inspiring diverse communities to collaborate and solve problems together, benefiting both SUSE customers and the open-source community (Yufen Chen, 2019).

In summary, open innovation was chosen as a moderating variable to provide insights into how digital capabilities and teamwork affect service innovation performance in a variable way under different levels of external cooperation and knowledge exchange. This approach reveals the importance of external knowledge acquisition and provides insights into how internal resources and capabilities can be optimized through strategic external collaboration in rapidly changing markets, highlighting the key role of open innovation in moderating an organization's innovation strategy and enhancing service innovation outcomes.

3. Research Methodology

3.1. Models and hypotheses

3.1.1. Research hypotheses

(1) Digital Transformation and Enterprise Service Performance Innovation

With the continuous development and application of digital technology, the digital transformation of businesses has become a key driver in enhancing service performance and innovation capacity. The accumulation and utilization of digital resources have become increasingly important. Within the framework of resource-based theory, it can be inferred that digital resources, as a unique and non-replicable asset, play a decisive role in creating competitive advantage for businesses.

Digital transformation encompasses the overhaul of enterprise infrastructure, the reshaping of business processes, the adjustment of organizational structures, and the updating of cultural concepts. These changes enable businesses to operate in a more flexible and efficient manner. Furthermore, leveraging digital technology to promote automation and intelligence helps optimize cost structures, improve operational efficiency, and maintain or even expand market share. Based on this, the following hypothesis is proposed:

H1a: Improvements in enterprise digital transformation positively impact financial performance.

In addition to financial performance, the digital transformation of businesses can significantly enhance market performance related to information flow and transparency. From an information perspective, digital transformation can optimize the acquisition, processing, and communication of information, thereby reducing the risks brought about by information asymmetry. In capital markets, transparent and timely information disclosure can effectively reduce uncertainty for investors and other stakeholders, thereby enhancing market confidence in and valuation of businesses. Based on this, the following hypothesis is proposed:

H1b: Improvements in enterprise digital transformation positively impact market performance.

Further analysis reveals that digital transformation isn't just about a company's current operational and market performance, but also its capacity to face future challenges - its dynamic capability. From this perspective, companies with a higher digitalization level possess stronger resource integration abilities compared to their peers. This enables them to swiftly respond to market changes, seize innovative opportunities, and effectively manage organizational knowledge assets. By enhancing dynamic capability, organizations are able to excel in areas such as new product development, service innovation, and operational model innovation. Based on this, we propose the following hypothesis:

H1c: Improvements in firms' digital transformation positively affect innovation performance.

The current focus of the business community lies in how to achieve better service performance and innovative outcomes through digital transformation. Research attempts to explain the positive correlation from a theoretical perspective. Some studies suggest that digital transformation is not merely a one-time technological upgrade, but a profound strategic change that involves comprehensive transformation of corporate culture, customer experience, and value creation methods. This transformation ensures that companies can sustainably drive innovation when faced with ever-changing market environments, constantly building and maintaining their core competitiveness.

In summary, digital transformation within a company demonstrates enormous potential in enhancing financial performance, improving market performance, and strengthening innovation performance. Building upon the aforementioned analysis, companies should increase their investment

and promotion efforts in digital transformation to actively explore the path of enhancing service performance and innovation through digital means.

(2) Digital transformation and open innovation

In the current era of digitalization, businesses are not only pursuing internal operational optimization but also empowering innovation practices. The continual enhancement of digital maturity has increasingly become a critical driver for open innovation. With the widespread application of cutting-edge technologies such as big data analytics, cloud computing, and artificial intelligence, enterprises have significantly strengthened their capabilities in accessing and leveraging external knowledge resources, providing reliable technological support and vast operational space for open innovation models.

By utilizing digital tools, businesses are able to detect and connect to previously inaccessible sources of knowledge, such as expert networks from different industries, research institutions, and even the wisdom of ordinary consumers. This cross-domain integration accelerates the diversified exchange of knowledge, injecting new thinking and solutions into innovation activities, thus expanding the paths for businesses to overcome technological bottlenecks and market constraints. The efficiency and interconnectedness of digital tools serve as catalysts for creating this transformative opportunity for enterprises.

The promotion of open innovation through digital transformation is also reflected in the form of collaborative innovation networks. Instead of going solo, businesses now engage in extensive partnerships through internet platforms to share knowledge, technology, and market information with external collaborators. In this process, digital technologies effectively reduce transaction costs for collaboration, enhance the absorption and re-creation capabilities of knowledge, and thereby ignite the vitality of innovation activities. Based on this, we propose the following hypothesis:

H2a: As the digital transformation of an organization improves, so does its open innovation.

(3) The mediating role of open innovation

Open innovation, as a strategic shift, has become an important bridge linking digital transformation and performance improvement for enterprises. By leveraging digital platforms such as collaborative crowdsourcing and online forums, companies can effectively absorb the essence of global thinking and innovative insights. This diverse demand and ability for knowledge integration are difficult to achieve with traditional closed innovation models.

Digital transformation creates a broader and more flexible innovation environment for enterprises, including rapid access to core technology information, tracking consumer trends, and real-time communication feedback. In this context, the influence of open innovation is further amplified. Through digital means, companies can more efficiently search for external innovation resources, reduce information asymmetry, and enhance their ability to solve complex problems. This ability not only accelerates product development cycles but also reduces related costs, thereby increasing the competitive advantage of enterprises in the highly competitive market.

Open innovation, as an intermediary, also manifests its impact on the performance of enterprises in the capital market. With the development of information technology, investors can quickly collect and process information about corporate innovation activities. The transparency and credibility of these activities are crucial to enhancing shareholder value. Through open innovation, companies demonstrate their investment and commitment to future technology trends, which enhances their brand image, boosts investor confidence, and ultimately promotes stock market performance.

Given the intermediary role of open innovation in enhancing enterprise efficiency, business leaders should pay attention to keenly identifying external innovation resources and strive to integrate these resources to drive the innovation process within their internal teams. Through continuous digital and innovation interactions, companies can cultivate the ability to adapt to future market changes and

bring sustained growth momentum.

Based on this, the following hypotheses are proposed:

H2b: Open innovation has a mediating effect between digital transformation and financial performance.

H2c: Open innovation has a mediating effect between digital transformation and market performance.

H2d: Open innovation has a mediating effect between digital transformation and innovation performance. performance.

(4) Group Collaboration and Service Performance Innovation

In the framework of building this research, the importance of teamwork as a core argument has received continuous attention. Team collaboration is seen as a potential driver for enhancing service innovation performance, prompting the research team to base their study on a comprehensive review of literature, theoretical and empirical research history indicating that close collaboration among cross-functional teams is positively correlated with the innovation performance of enterprises. Collaborative efforts not only encompass close connections among members, but also signify the full utilization of resources and the deep integration of knowledge, all of which are critical factors driving service innovation. The adequacy of teamwork along the innovation chain is the cornerstone for enterprises to enhance their innovation performance. This hypothesis stems from a fundamental assumption that effective teamwork can accelerate idea exchange, stimulate creativity, and facilitate the prompt resolution of issues, ultimately optimizing the outcomes of service innovation for enterprises.

Furthermore, problem-solving ability, as an important component of teamwork, is directly linked to the innovation performance of enterprises when they face complex challenges. In today's landscape where innovation demands frequent iterations and rapid responses, the agility and capability of teams in addressing problems determine whether they can timely resolve obstacles encountered during the innovation process, thus exerting a positive impact on service innovation performance. Modern business environments are fiercely competitive and constantly evolving, making the improvement of service innovation performance a necessary path for survival and development. The teamwork capabilities and problem-solving skills have been widely supported in literature, directly influencing a company's innovation capabilities. Therefore, by bridging theory and practice through this hypothesis, an attempt is made to illustrate the positive role of teamwork on service innovation performance under the backdrop of digital acceleration.

On this basis, the following hypotheses are proposed:

H3a: In the process of collaborative innovation, the more adequate the team cooperation among the subjects of the innovation chain, the higher the innovation performance of the enterprise

H3b: In the process of collaborative innovation, the stronger the team problem solving ability among the subjects of the innovation chain, the higher the enterprise innovation performance.

3.1.2. Construction of theoretical models

During the process of constructing a theoretical model, the author delved deeply into the intrinsic connection between digital transformation and firm performance. This model originated from a meticulous review of existing literature and encompasses how the level of digitization influences firm performance through various mechanisms. The study considers how firms utilize their knowledge capital to facilitate the integration of digital technologies, and further explores how these technologies promote open innovation practices. In order to better comprehend the complexity of this relationship and its potential variations, the model analyzes the interactions among multiple variables.

Through further analysis, we developed seven research hypotheses that provide insights into the potential interactive effects between digitization levels, open innovation and firm performance. These hypotheses were incorporated into a theoretical model as shown in Figure 1. The figure illustrates the expected relationships between the independent, dependent, mediating, and moderating variables. Each variable was rigorously defined and operationalized to ensure the accuracy of the study and the reliability of the results. The final design of the model is intended to provide an intuitive theoretical

framework for understanding the impact of digital capabilities on firms' service innovation performance. This framework can help scholars and practitioners understand how digital investments translate into real competitive advantages for firms.

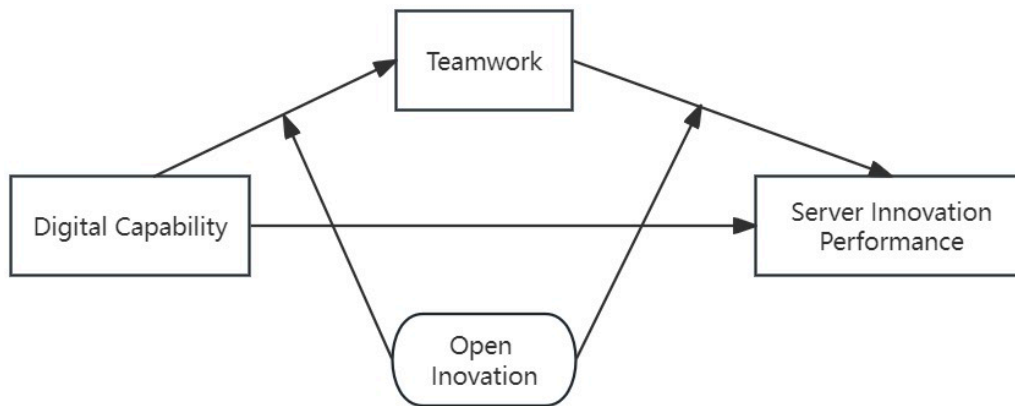


Fig.1. A theoretical model of the relationship between digital capability, service innovation performance , teamwork and open innovation

In order to test the relationship between the influence of digital competence, service innovation performance, teamwork and open innovation, this paper constructs a benchmark regression model based on the fixed effect model expressed as equations (1)-(3):

$$ROA_{i,t} = \alpha_0 + \alpha_m Digi_{i,t} + \sum \alpha_n Control_{i,t} + Industry_i + Year_t + \varepsilon_{i,t} \quad (1)$$

$$TobinQ_{i,t} = \alpha_0 + \alpha_m Digi_{i,t} + \sum \alpha_n Control_{i,t} + Industry_i + Year_t + \varepsilon_{i,t} \quad (2)$$

$$GP_{i,t} = \alpha_0 + \alpha_m Digi_{i,t} + \sum \alpha_n Control_{i,t} + Industry_i + Year_t + \varepsilon_{i,t} \quad (3)$$

3.2. Research design

3.2.1. Data sources

The data source provides the foundational information blocks for research work. Within the research process, both primary and secondary data are common types of data. Primary data is directly collected from relevant experiments, surveys, or observational activities, and due to its originality, it can most directly reflect the state of the research question. However, the collection process is often time-consuming and costly. In contrast, secondary data already exists in public publications, previous studies, or various databases, making it more accessible and relatively lower in cost. However, the relevance and timeliness of the data may be limited. To ensure the quality of research, data must come from reputable sources. For example, reports released by the government, academically peer-reviewed journals, and statistical data provided by international organizations such as the United Nations or the World Economic Forum are all valuable sources for data collection. These types of data have the advantage of authenticated authenticity and authority, enhancing the credibility of the research. The ideal data source should be of high quality and closely related to the research objectives. Researchers need to critically examine the origin, collection methods, and reliability of the selected data sources to ensure data accuracy. Furthermore, considering the diversity of data sources, researchers often combine multiple sources for a study, as this approach not only enriches the research but also helps verify the effectiveness of the data through comparative analysis. Selecting appropriate data sources not only directly influences the results and quality of the research but also contributes to establishing the credibility and authority of the research in the academic and business communities.

3.2.2. Data analysis methods

The selection of data analysis methods provides support for the quality of research outcomes. When processing and interpreting research data, the applicability and effectiveness of analytical techniques are crucial for insights into underlying patterns and trends. Traditional data analysis methods, such as descriptive statistics, provide basic characteristics of the data, such as mean, median, mode, and standard deviation, while inferential statistics further evaluate general conclusions of the data through hypothesis testing and confidence intervals.

In more complex analytical scenarios, researchers may employ advanced analytical techniques, including but not limited to regression analysis, analysis of variance, cluster analysis, and principal component analysis. These methods not only identify the strength of relationships between variables, but also help discover potential groups within the dataset or reduce dimensions for better data interpretation. Additionally, with the development of machine learning and artificial intelligence technologies, these advanced analytical techniques have been expanded and enhanced, with deep learning algorithms such as neural networks excelling in interpreting large-scale complex data.

Choosing the appropriate data analysis methods should be based on research objectives, data types, data scale, and expected analysis results. Quantitative data is typically analyzed using statistical methods, while qualitative data may utilize content analysis or thematic analysis methods. During implementation, ensuring data accuracy and analysis transparency is a prerequisite for ensuring research integrity. Using statistical software (such as SPSS, R, Python, etc.) for data analysis can improve efficiency, while also ensuring the reasonableness of the analysis process and the standardization of data processing.

3.2.3. Variable Definition

(1) Dependent variable

The dependent variable chosen for this study focuses on measuring the performance of firms in service innovation. This variable is chosen because the impact of service innovation outcomes has received much attention, and it can rigorously reflect the achievements of firms in terms of new service development, service process optimization, and customer experience improvement. Service innovation performance includes both specific business indicators such as revenue growth, profitability improvement, and market share change, as well as non-financial indicators such as customer satisfaction, loyalty, and brand recognition. By comprehensively considering these indicators, this study aims to deeply explore and reveal the actual impact of companies' service innovation activities on their performance. In addition, the measurement of service innovation performance as a dependent variable will also depend on the relative performance of other enterprises in the same industry to ensure the reliability and comparability of the evaluation results.

(2) Independent variable

In the framework of this study, the independent variable is explicitly defined as digital capability, which reflects an examination of firms' efforts in adopting and applying digital technologies. Digital transformation encompasses a wide range of activities including, but not limited to, the implementation of Enterprise Resource Planning (ERP) systems, the utilization of cloud computing services, the application of big data analytics, the integration of mobile technologies, and the introduction of Artificial Intelligence (AI). These technology transformation activities are recognized as important ways for companies to increase operational efficiency, create new revenue streams, and improve customer experience. This study aims to explore the role and significance of enterprise digital capabilities in enhancing service innovation performance by measuring and analyzing these activities. Considering the multidimensional nature of digital capabilities, the research design will include a range of metrics to accurately capture their specific impact on service innovation outputs.

(3) Intermediary Variables

In this study, teamwork plays a crucial role as a mediating variable that bridges the relationship between digital capabilities and service innovation performance. By facilitating knowledge sharing, stimulating creative thinking, and enhancing cross-departmental communication and coordination, teamwork can effectively transform an organization's digital capabilities into actual service innovation outcomes. This process not only reveals the key role of teamwork in facilitating the transformation of digital resources into innovation performance, but also highlights the importance of optimizing team interaction and cooperation mechanisms in improving service innovation performance. This study aims to effectively connect the relationship between digital capabilities and innovation performance by facilitating knowledge sharing, stimulating innovative thinking, accelerating innovation implementation, and enhancing cross-border cooperation. Team collaboration was chosen as a mediating variable because this mediating role emphasizes the importance of intra-team interaction and cooperation, revealing the potential of service innovation capabilities that can be significantly improved by optimizing team structure and collaboration mechanisms.

(4) Moderator variable

The moderating variable involved in this study is the concept of open innovation, which reflects the interaction and cooperation between enterprises and the external environment in the innovation process. Open innovation refers to the fact that firms not only rely on internal resources and capabilities in their R&D activities, but also actively absorb and utilize external knowledge and technology, and even share risks and benefits with other organizational partners. This study aims to measure the extent of open innovation to assess how it mediates the relationship between the independent and dependent variables, e.g., to explore whether open innovation strengthens or weakens the impact of digital capabilities on firms' service innovation performance. Operationalizing open innovation as a moderating variable could include quantifiable indicators such as the number of collaborative projects, the diversity of knowledge acquisition, and the breadth and depth of innovation networks. Considering these factors together allows for a more comprehensive understanding of the drivers behind firm performance.

4. Results and Discussion

4.1 Validity test

4.1.1. Validated factor analysis of digital transformation

Referring to Table 1 it can be seen that the fitness of the digital transformation model is significant, which can be concluded from the statistical indicators. The value of the model coefficient χ^2 / df is 1.719, which is much lower than the recommended upper limit of 3, indicating that the model has a good fit with the data. Meanwhile, the Root Mean Square Error Approximation RMSEA is 0.053, which is less than the commonly used threshold of 0.08, indicating a good enough fit within the error domain. Other model metrics such as the comparative fit index CFI of 0.992, the incremental fit index TLI of 0.987 and the canonical fit index NFI of 0.982 exceeded the acceptance criterion of 0.9, confirming the utility and high degree of fit of the model.

Table 1. Validated factor analysis model fit coefficients for digital transformation

Index of fit degree	χ^2 / df	RMSEA	CFI	TLI	NFI
Actual result	1.719	0.053	0.992	0.987	0.982
Proposed scope	<3	<0.08	>0.9	>0.9	>0.9

Based on the results of the convergent validity test in Table 2, it can be observed that the loading values of the digital transformation factors exceeded the criterion of 0.5, the CR of the combined reliability was higher than 0.7, and the AVE of the mean extracted variance exceeded 0.5, all of which indicate that each of the constructs presented the desired representativeness and convergent validity.

Table 2. convergent validity test results for digital transformation

path	Estimate	CR(combined reliability)	AVE(mean variance taken)
DT1 ← Digital transformation	0.818		
DT2 ← Digital transformation	0.865		
DT3 ← Digital transformation	0.759	0.898	0.595
DT4 ← Digital transformation	0.752		
DT5 ← Digital transformation	0.741		
DT6 ← Digital transformation	0.680		

In short, through these detailed statistical indicators and testing processes, the factor analysis model of digital transformation is proved to have strength and validity, with clear intrinsic correlations among the components, thus providing a solid foundation for future research and pointing out a clear direction for practical applications in related fields.

4.1.2. A validated factor analysis of open innovation

When assessing the statistical soundness of the open innovation model, confirmatory factor analysis provides the necessary quantitative evidence. This analysis involves testing a series of parameters, all of which meet the relevant standards for model validation. The specific data, as shown in Table 3, reveal that the model fit coefficient χ^2/df is 1.436, below the conventional threshold of 3. This indicates a limited discrepancy between the hypothesized assumptions of the model and the actual data, suggesting a high level of credibility in the simulation results. Additionally, the root mean square error of approximation (RMSEA) is 0.041, below the standard value of 0.08, indicating a good fit between the model and the collected data. Furthermore, the comparative fit index (CFI) and the Tucker-Lewis index (TLI) perform remarkably well, scoring 0.990 and 0.987 respectively, surpassing the benchmark of 0.9. Additionally, the normed fit index (NFI) achieves a score of 0.969, indicating a strong model generalization. These results collectively demonstrate an excellent fit between the data and the constructed open innovation model, reinforcing its effectiveness.

Table 3. Table of coefficients of fit for the validated factor analysis model of open innovation

Index of fit degree	χ^2/df	RMSEA	CFI	TLI	NFI
Actual result	1.436	0.041	0.990	0.987	0.969
Proposed scope	<3	<0.08	>0.9	>0.9	>0.9

As can be interpreted from Table 4, the test of convergent validity yielded positive results, showing that the factor loadings of the respective questions related to inward and outward open innovation were above the level of 0.5, indicating that these questions have significant weights in the respective factors. Meanwhile, the composite reliability (CR) is greater than 0.7, and the average variance extracted (AVE) are over 0.5, which is a strong evidence of the model construction, and further shows the consistency and representativeness of the questions, which proves that they are significantly correlated and well converged in the model.

Table 4. Convergent validity test results for open innovation

path	Estimate	CR(combined reliability)	AVE(mean variance taken)
IOI1 ←Introverted open innovation	0.776		
IOI2 ←Introverted open innovation	0.764		
IOI3 ←Introverted open innovation	0.889	0.893	0.627
IOI4 ←Introverted open innovation	0.766		
IOI5 ←Introverted open innovation	0.757		
EOOI1 ←Outward-oriented open innovation	0.777		
EOOI2 ←Outward-oriented open innovation	0.751		
EOOI3 ←Outward-oriented open innovation	0.797	0.903	0.652
EOOI4 ←Outward-oriented open innovation	0.908		
EOOI5 ←Outward-oriented open innovation	0.794		

In summary, these statistics and parametric analyses provide a firm statistical basis for the reliability of open innovation in practice and related research, thus pointing the way to a scientific, data-driven approach for firms interested in adopting an open innovation strategy.

4.1.3. Validated Factor Analysis of Firms' Service Innovation Performance

The validated factor analysis of corporate service innovation performance from multiple perspectives is a key step in determining whether its model is scientific and valid. According to the latest statistical data, the assessment model of innovative performance exhibits a remarkable fit. This is evident from a series of complex indicators, as shown in Table 5. The value of χ^2/df is 1.434, significantly lower than 3, which is an important criterion for evaluating model fit and reflects a high level of model accuracy. Additionally, the value of RMSEA is 0.041, far below the threshold of 0.08, suggesting that the residual level is within an acceptable range. By examining other key indices, the comparative fit index (CFI) is 0.984, significantly exceeding the traditional benchmark of 0.9, indicating a high degree of alignment between the model and observed data. The Tucker-Lewis index (TLI) and the normed fit index (NFI) both reach 0.980 and 0.949, respectively, meeting or surpassing their standard thresholds and further confirming the robustness of the model.

Table 5. Table of coefficients of fit for validated factor analysis model of innovation performance of business services

Index of fit degree	χ^2 / df	RMSEA	CFI	TLI	NFI
Actual result	1.434	0.041	0.984	0.980	0.949
Proposed scope	<3	<0.08	>0.9	>0.9	>0.9

Based on the comprehensive Table 6, Three key dimensions of innovation performance in

business services: financial performance, customer performance and internal performance - all exhibit factor loadings above 0.5. This suggests a high correlation and significant explanatory power between each component and the overall concept. Furthermore, the composite reliability (CR) value exceeds 0.7, and the average variance extracted (AVE) is greater than 0.5, indicating good consistency and reasonable levels of explanation between the items, ensuring the convergence validity of the model.

Table 6. Convergent validity test results for firms' service innovation performance

path	Estimate	CR(combined reliability)	AVE(mean variance taken)
FP1 ←Service innovation financial performance	0.896		
FP2 ←Service innovation financial performance	0.725	0.850	0.589
FP3 ←Service innovation financial performance	0.688		
FP4 ←Service innovation financial performance	0.745		
CP1 ←Service innovation Customer performance	0.761		
CP2 ←Service innovation Customer performance	0.767	0.887	0.612
CP3 ←Service innovation Customer performance	0.728		
CP4 ←Service innovation Customer performance	0.765		
CP5 ←Service innovation Customer performance	0.882		
IP1 ←Service innovation internal performance	0.743	0.895	0.632
IP2 ←Service innovation internal performance	0.855		
IP3 ←Service innovation internal performance	0.763		
IP4 ←Service innovation internal performance	0.799		
IP5 ←Service innovation internal performance	0.810		

In summary, the results of these detailed analyses, such as serving as the cornerstone of a stable constructed model, provide strong data support for defining and enhancing a company's successful performance in service innovation. By recognizing and retaining the needed question items, companies are able to understand and advance their service innovation performance in greater depth based on sound scientific methodology.

4.1.4. Distinguishing validity tests

During the examination of discriminant validity, researchers typically focus on the associations between various conceptual dimensions and compare these associations with their respective reliabilities. The data presented in Table 7 reveals the interrelationships between digital transformation, two types of open innovation (outward and inward), and three dimensions of service innovation performance (financial performance, customer performance, and internal performance). The analysis indicates that the correlation coefficients in these domains do not exceed the square root of the average variance extracted (AVE) of their respective dimensions. The results suggest distinct differentiations among these six domains, verifying the reliable discriminant validity of the model.

Table 7. Results of sample question-item discriminant validity test

variable	Mean	Std.	1	2	3	4	5	6
1. Digital transformation	4.945	1.649	0.771					
2. Introverted open innovation	4.784	1.302	0.428***	0.792				
3. Outward-oriented open innovation	4.850	1.392	0.514***	0.309***	0.807			
4. Service innovation financial performance	4.955	1.416	0.534***	0.498***	0.446***	0.768		
5. Service innovation customer performance	4.810	1.432	0.495***	0.522***	0.397***	0.551***	0.782	
6. Internal performance of service innovation	4.998	1.451	0.381***	0.550***	0.367***	0.507***	0.519***	0.795

Note: The diagonal line is the square root of the AVE corresponding to each variable; *** indicates $p < 0.001$

As verified by comparing the correlation coefficients with the square root of the AVE, the concepts represented by each building block are clearly differentiated from the other variables, which is indispensable in the implementation of effective strategies and decision-making processes. This distinguishing power ensures a clear definition between the model variables and provides an accurate theory for subsequent research.

4.2. Homologous method bias test

To ensure the validity of the research findings, the detection of method bias is a crucial step as it may introduce errors in the assessment of relationships between research variables. In this study, the Harman single-factor test was adopted to evaluate whether the data was affected by common method bias. This analysis was conducted using the support of the SPSS 20.0 software package and involved an unrotated exploratory factor analysis. The results presented in Table 8 indicate that, under the unrotated condition, there are six factors with eigenvalues greater than 1. This indicates that more than a single factor is extracted, suggesting that the data structure is not dominated by a single dimension. Additionally, the variance explained by the largest factor is only 34.59%, which is below the conventional threshold of 40%. This indicates that the largest factor does not explain a significant amount of variance, further supporting the claim that common method bias is not an issue.

Table 8. Results of the common method bias test

ingredient	Total	Percent variance of initial eigenvalue	Accumulation (%)
1	10.377	34.590	34.590
2	3.234	10.780	45.370
3	2.205	7.351	52.722
4	1.945	6.484	59.205
5	1.805	6.017	65.223
6	1.601	5.335	70.558

These test results instill confidence and demonstrate that the data collection process in this study is unaffected by methodological biases, thereby ensuring the reliability and validity of the research findings. In this manner, confidence in the research results is ensured and supports the applicability of the corresponding research conclusions to managerial practices.

4.3. Results of hypothesis testing

Upon conducting a systematic examination of the assumptions underlying the research model, a set of results was obtained and meticulously documented in Table 9. This compilation presents the test statistics for each hypothesis, including regression coefficients, t-values, as well as relevant confidence intervals and p-values, thus providing a basis for accepting or rejecting the hypotheses. Specifically, emphasis was placed on the direct relationship between digitization levels and firm performance, as well as the indirect effect mediated by open innovation. The examination revealed that certain hypotheses were strongly supported by the data, evidenced by statistically significant indicators, while others failed to receive confirmation at the predetermined level of significance. These findings refine the theoretical framework and offer guidance for future research, while also providing an empirical foundation for professionals in related fields. The examination process employed appropriate statistical methods to ensure the validity of the results, thereby offering reliable validation for the theoretical model.

Table 9. Results of research hypothesis testing

label	hypothesis	result
H1	Firms' digital capabilities positively affect service innovation performance.	support
H1a	The ability of firms to process digital information positively affects service innovation performance.	support
H1b	Firms' digital technology application capabilities positively affect service innovation performance.	support
H1c	Firms' digital strategic planning capabilities positively affect service innovation performance.	support
H2	Teamwork mediates the relationship between digital capabilities and service innovation performance.	support
H2a	Teamwork mediates the relationship between firms' digital information processing capabilities and service innovation performance.	Support
H2b	Teamwork mediates the relationship between firms' digital technology adoption capabilities and service innovation performance.	Support
H2c	Teamwork mediates the relationship between firms' digital strategic planning capabilities and service innovation performance.	nonsupport
H3	Open innovation moderates the relationship between digital capabilities and service innovation performance.	support
H3a	Open innovation reinforces the positive impact of firms' digital information processing capabilities on service innovation performance.	support
H3b	Open innovation strengthens the positive impact of firms' digital technology application capabilities on service innovation performance.	support
H3c	Open innovation strengthens the positive impact of firms' digital strategic planning capabilities on service innovation performance.	nonsupport
H4	Open innovation moderates the mediating effect of teamwork on service innovation performance.	support
H4a	Open innovation reinforces the positive impact of teamwork on service innovation performance.	support
H4b	In firms with a high degree of open innovation, teamwork further enhances service innovation performance by increasing mutual trust and a sense of common purpose among team members.	support
H4c	Open innovation strengthens the mediating role of teamwork in achieving service innovation performance by facilitating the absorption and integration of external knowledge.	support

5. Conclusion

This study examines the relationship between digital capabilities, team collaboration, and service innovation performance, and analyzes the moderating role of open innovation in this process, revealing several key findings. Firstly, the research confirms that digital capabilities directly and positively influence service innovation performance, emphasizing the importance of technological resources and capabilities in the era of digital economy. Secondly, team collaboration as a mediating variable not only enhances the impact of digital capabilities on service innovation performance, but also underscores the role of interdisciplinary cooperation and internal communication in promoting innovation. Furthermore, the analysis of the moderating effect of open innovation indicates that interactions and collaboration with the external environment can significantly influence how internal resources and capabilities are transformed into innovative outcomes, providing a new perspective on how organizations deploy their digital and collaborative resources in an open innovation environment.

These findings are of great significance for both theory and practice. Theoretically, this study expands the understanding of the impact of digital capabilities, team collaboration, and open innovation on service innovation performance, particularly by offering new insights into the mediating and moderating mechanisms. From a practical perspective, the study emphasizes the importance for organizations to invest in enhancing digital capabilities and promoting team collaboration, while actively exploring opportunities for collaboration with external resources to optimize their service innovation processes and outcomes.

Future research could further explore the mechanisms of these variables in different industries and cultural backgrounds, as well as how to strengthen these impacts through strategic and management practices. Additionally, considering the rapid changes in technological and market environments,

studying how open innovation affects organizational adaptability and long-term innovation capabilities would also be a valuable direction.

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