



Review

Effect of R&D innovation cooperation on corporate innovation: the mediating role of digital transformation capability

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Abstract: In the rapidly evolving digital economy, service firms face increasing pressure to adopt open innovation frameworks that actively leverage external knowledge. This study investigates the impact of Research and Development (R&D) Innovation Cooperation on Corporate Innovation within service enterprises, focusing on the structural mediating role of Digital Transformation Capability. Drawing upon the Resource-Based View (RBV), Dynamic Capability Theory, and Open Innovation Theory, a research model was developed and tested using Structural Equation Modeling (SEM). The empirical findings reveal that R&D innovation cooperation serves as a powerful antecedent that significantly enhances a firm's digital transformation capability. Furthermore, this newly developed digital capability exerts a positive direct effect on corporate innovation by enabling data-driven decision-making and operational flexibility. Crucially, the results demonstrate that digital transformation capability plays a vital mediating role in the relationship between R&D cooperation and corporate innovation. This underscores that external knowledge acquired through collaboration yields substantial innovative performance only when successfully integrated into the firm's internal digital dynamic processes. By explicating the inner mechanism of transforming external alliances into internal digital capabilities, this research offers valuable academic and practical insights for formulating digital innovation strategies in service industries.

Keywords: R&D innovation cooperation; digital transformation capability; corporate innovation; dynamic capability theory; service enterprises

1. Introduction

In recent years, the business environment surrounding enterprises has exhibited a significantly higher level of uncertainty than in the past, driven by the rapid development of digital technologies, intensifying global competition, diversifying customer demands, and shortening technological innovation cycles. In particular, digital technologies—represented by artificial intelligence (AI), big data, cloud computing, the internet of things (IoT), and digital platforms—are fundamentally reshaping industrial value chains. Consequently, corporate research and development (R&D) activities are also swiftly shifting toward a cooperation-oriented innovation system grounded in open innovation paradigms.

While internal R&D capabilities were traditionally recognized as the core determinant of innovation performance under the conventional closed R&D model, the ability to acquire and utilize new knowledge through collaboration with external organizations has recently emerged as a critical source of corporate competitiveness. R&D innovation cooperation with universities, research institutes, suppliers, customers, and competing firms is widely acknowledged as an effective strategy. It allows companies to rapidly secure technologies and knowledge they lack, disperse the risks associated with

innovation, and reduce technological development costs. This shift underscores that, within the open innovation framework, inter-firm cooperative networks serve as a pivotal mechanism for generating innovative outcomes.

However, R&D innovation cooperation does not automatically guarantee high levels of corporate innovation. Even among firms engaging in identical levels of innovation cooperation, substantial variations in innovation performance exist. This implies that the outcomes of innovation can vary depending on how effectively a firm integrates and utilizes the technologies and information acquired through external collaboration within the organization. In other words, rather than the act of innovation cooperation itself, the internal capability to transform external resources into a corporate competitive advantage is highly likely to function as a crucial factor determining innovation performance.

Among these internal capabilities, the concept receiving the most significant attention recently is digital transformation (DT) capability. Digital transformation does not merely entail the adoption of information technology or the computerization of business tasks. Instead, it refers to an organization-wide capability to innovate business processes, organizational culture, decision-making structures, customer value creation methods, and business models based on digital technologies. Firms possessing high digital transformation capability can rapidly absorb diverse external knowledge and technologies, develop new products and services through data-driven decision-making, and respond agilely to market changes. Therefore, digital transformation capability is expected to serve as a vital link in the process through which R&D innovation cooperation translates into actual corporate innovation.

Indeed, digital transformation is emerging as a core factor determining innovation performance not only in manufacturing but also in the service industry. Given that service firms possess strong intangible and knowledge-intensive characteristics, service innovation, customer experience innovation, and platform-based business model innovation leveraging digital technologies have become critical determinants of sustainable competitive advantage. Hence, within service enterprises, digital transformation capability needs to be understood as a strategic resource that enhances the efficiency of R&D activities and maximizes innovation performance.

South Korea provides an especially meaningful empirical context for examining the relationship between R&D innovation cooperation, digital transformation capability, and corporate innovation. As one of the world's leading digital economies, South Korea has continuously promoted national strategies aimed at accelerating digital transformation across industries. Government initiatives, including the digital new deal and the digital platform government strategy, have emphasized the diffusion of artificial intelligence, cloud computing, big data, and digital platforms while encouraging collaborative R&D among firms, universities, research institutes, and public organizations. In particular, the service sector has received increasing policy attention because digital technologies are regarded as essential drivers of service innovation, productivity improvement, and global competitiveness.

These national policy initiatives have created an institutional environment in which service enterprises actively participate in collaborative innovation while simultaneously investing in digital transformation capabilities. Consequently, South Korea offers an appropriate research setting for investigating how external R&D cooperation is transformed into corporate innovation through internal digital capabilities. The findings of this study therefore contribute not only to understanding innovation mechanisms within the Korean service industry but also to providing practical implications for other economies pursuing similar digital transformation and innovation policies.

This perspective can be theoretically elucidated by the resource-based view (RBV) and dynamic capability theory. The RBV posits that valuable, rare, inimitable, and non-substitutable (VRIN) resources owned by a firm generate sustainable competitive advantage. However, in a rapidly changing external environment, merely possessing superior resources is insufficient to sustain a competitive edge. In response, dynamic capability theory argues that a firm's capacity to continuously integrate, reconfigure, and transform its resources into new capabilities in response to environmental shifts determines its long-term competitive advantage. From this viewpoint, R&D innovation cooperation represents the process through which a firm secures diverse external knowledge and technology, whereas digital transformation capability can be understood as a dynamic capability that transforms these acquired resources into internal innovation capabilities. Ultimately, corporate innovation can be viewed as an outcome variable manifesting through the interaction of these resources and capabilities.

Furthermore, open innovation theory provides an important theoretical foundation for this study. Open innovation explains that firms can improve their innovation performance by actively utilizing external ideas and technologies alongside internal R&D. However, the mere acquisition of external knowledge does not guarantee innovation; an organizational capability to combine the acquired knowledge with internal processes and convert it into new value is essential. In this regard, digital transformation capability can be understood as a core mechanism that amplifies the efficacy of open innovation.

Prior studies have primarily focused on identifying the direct relationship between R&D innovation cooperation and corporate innovation, reporting that higher levels of cooperation lead to enhanced innovation performance. However, explanations regarding the internal mechanisms through which cooperation translates into innovation remain relatively scarce. In particular, empirical research verifying the structural relationship between R&D innovation cooperation and corporate innovation by establishing digital transformation capability as a mediator is highly limited. Most existing studies treat digital transformation either as an independent variable or an environmental factor, leaving the mediating role of digital transformation capability—specifically in linking cooperation effectiveness to tangible innovation performance—insufficiently validated.

This research gap poses a significant limitation in understanding corporate innovation strategies within the digital economy. This is because there is a lack of clear empirical evidence regarding whether firms can secure innovation performance solely by expanding external collaboration, or whether the process of transforming such collaboration into digital-based organizational capabilities is imperative. Therefore, investigating the causal relationship between innovation cooperation and corporate innovation, centered on digital transformation capability, is expected to offer crucial insights not only from an academic standpoint but also for formulating corporate innovation strategies.

Accordingly, this study aims to analyze the impact of R&D innovation cooperation on corporate innovation within service enterprises and empirically test the mediating effect of digital transformation capability using structural equation modeling (SEM). Specifically, the objectives are threefold: first, to identify the impact of R&D innovation cooperation on digital transformation capability; second, to empirically examine the effect of digital transformation capability on corporate innovation; and third, to explain the internal mechanism linking innovation cooperation to innovation performance by verifying whether digital transformation capability plays a mediating role in the relationship between R&D innovation cooperation and corporate innovation.

This study holds the following academic and practical contributions. First,

it extends the literature on R&D innovation cooperation by proposing an internal mediating mechanism—digital transformation capability—thereby addressing the limitations of prior research that predominantly focused on direct effects. Second, it enhances the theoretical explanatory power of corporate innovation in the digital era by proposing a research model that integrates the resource-based view, dynamic capability theory, and open innovation theory. Third, by empirically validating the pathways through which digital transformation capability influences corporate innovation via structural equation modeling and mediation analysis, this study provides actionable, practical implications for formulating digital innovation strategies and R&D cooperation policies for service enterprises.

2. Theoretical background and hypothesis development

2.1. R&D innovation cooperation

2.1.1. Concept of R&D innovation cooperation

In recent years, the business environment surrounding enterprises has shifted in a way that makes it increasingly difficult to secure a sustainable competitive advantage solely through internal R&D capabilities, as the pace of technological innovation accelerates and the lifecycles of products and services continue to shorten. In particular, the development of digital technologies and the intensifying global competition in technology require firms to actively utilize diverse external technologies and knowledge. This shift has served as a pivotal catalyst for transitioning the R&D paradigm from closed innovation to open innovation. R&D innovation cooperation refers to strategic collaborative activities in which firms jointly perform R&D and share technologies and knowledge with various external organizations—such as universities, research institutes, suppliers, customers, competitors, and government agencies—to generate innovative outcomes. This encompasses a broad concept that includes not only simple joint R&D but also the exchange of technological information, joint patent development, joint product development, collaborative problem-solving, and continuous knowledge exchange.

Prior literature has defined R&D cooperation from various perspectives. Chesbrough (2003), from an open innovation perspective, argued that firms can maximize their innovation performance by actively leveraging external ideas and technologies alongside internal R&D. From this viewpoint, R&D innovation cooperation is understood not merely as the adoption of external technology, but as an innovative activity that jointly creates new knowledge through continuous interaction with external organizations. Powell et al. (1996) explained that technological innovation is increasingly becoming network-based and that inter-firm cooperation plays a critical role in acquiring new technological knowledge and enhancing innovation capabilities. Specifically focusing on the biotechnology industry, they empirically demonstrated that inter-firm cooperative networks are crucial factors determining R&D performance. Furthermore, Hagedoorn (2002) defined R&D cooperation as a representative form of strategic alliance, explaining it as an efficient innovation strategy to cope with technological uncertainty and rising R&D costs. Through cooperation, firms can disperse R&D investment risks and secure diverse specialized expertise, thereby increasing the probability of successful technological innovation.

The importance of R&D cooperation is also steadily increasing in the service industry. Unlike manufacturing firms, service enterprises secure their competitiveness primarily through intangible assets and customer experiences; thus, collaboration with various external stakeholders serves as a critical determinant of innovation performance. Particularly in industries grounded in digital technologies—such as platform services, AI-driven services, fintech, and digital healthcare—cooperation with external organizations is recognized as a core element for driving new service innovation.

2.1.2. Characteristics of R&D innovation cooperation

R&D innovation cooperation possesses several distinct features that differentiate it from general business collaboration. First is the knowledge-based characteristic. The core objective of R&D cooperation is not merely the sharing of tangible resources, but the joint creation of new technological knowledge. Consequently, both tacit and explicit knowledge are exchanged simultaneously during the collaborative process, and the ability to integrate this knowledge determines the ultimate innovation performance. Second is complementarity. Since most firms find it challenging to secure all necessary technologies internally, they utilize the specialized expertise owned by external organizations to complement their internal capabilities. Suppliers provide production technologies, universities offer foundational technologies, and customers supply market information, collectively enhancing the quality of innovation. Third is risk sharing. In recent high-tech fields, R&D costs and failure risks are continually escalating. Joint R&D provides the advantage of distributing investment costs and collectively bearing the risks associated with technological development failures. Fourth is the learning effect. Repeated cooperation facilitates inter-organizational learning and enhances a firm's absorptive capacity. This learning effect accumulates as a long-term asset that positively influences future innovation activities. Fifth is openness. Recent studies underscore that innovation performance driven by external collaboration is becoming more critical than internal R&D alone, leading firms to construct open innovation ecosystems by collaborating with diverse innovation actors.

2.1.3. Theoretical foundations of R&D innovation cooperation

In this study, R&D innovation cooperation can be elucidated primarily through Open innovation theory, the RBV, and dynamic capability theory. Open innovation theory presents a new paradigm suggesting that firms should execute innovation through collaboration with external organizations rather than relying solely on internal R&D. Chesbrough (2003) argued that as firm boundaries become increasingly permeable, enterprises that actively leverage external ideas and technologies achieve higher innovation performance. Under the RBV, the technologies and knowledge acquired through external collaboration are also regarded as strategic resources of the firm. However, merely possessing these resources does not automatically generate a competitive advantage; they function as valuable resources only when effectively utilized within the organization. Dynamic capability theory explains that a firm's capacity to continuously reconfigure its resources and transform them into new capabilities in response to environmental shifts is crucial. In other words, R&D innovation cooperation represents the process of acquiring external resources, and the subsequent process of transforming these resources into digital technologies and organizational capabilities ultimately determines corporate innovation.

2.1.4. Prior empirical research on R&D innovation cooperation

The majority of existing literature reports that R&D innovation cooperation exerts a positive influence on corporate innovation. Powell et al. (1996) asserted that inter-firm cooperative networks enhance R&D productivity and stimulate technological innovation. Hagedoorn (2002) found that firms engaging in international R&D cooperation exhibit higher innovation performance compared to those conducting R&D independently. Laursen and Salter (2006) suggested that while networks with diverse external collaboration partners increase innovation performance, an excessively high level of collaboration can increase management costs, thereby diminishing the innovation effects. This implies that the quality and management capability of collaboration are more critical than the mere quantity of cooperation. Belderbos, Carree, and Lokshin (2004) analyzed that cooperation

with customers, suppliers, and universities has a positive impact on both product and process innovation. Notably, they reported that collaboration with universities yields the greatest effect on long-term technological innovation.

Similar findings have been documented in domestic studies. Recent research focusing on service firms has confirmed that R&D innovation cooperation is an essential factor that improves corporate innovation and business performance. In particular, firms participating in government-sponsored R&D projects exhibit higher levels of external cooperation and superior innovation performance. However, most of these existing studies predominantly analyze only the direct relationship between R&D innovation cooperation and innovation performance. They fall short of fully explaining the internal mechanism through which the technologies and information acquired via collaboration are converted into innovation outcomes through intermediate organizational capabilities.

2.1.5. Relationship between R&D innovation cooperation and digital transformation capability

Recent advancements in digital technology are fundamentally reshaping the modes of R&D cooperation. Enterprises are increasingly utilizing AI, cloud computing, big data, and digital platforms to share R&D information in real time, thereby expanding the scope of collaboration to a global scale. In this context, digital transformation (DT) capability is recognized as a core organizational competence required to execute such collaboration effectively. Firms actively engaging in R&D cooperation tend to establish diverse digital platforms, implement data-driven decision-making systems, and enhance overall digital proficiency across the organization. From the lens of dynamic capability theory, the process of integrating knowledge acquired through external collaboration with internal digital systems serves as a pivotal mechanism for generating a sustainable competitive advantage. Therefore, R&D innovation cooperation can be understood as an essential antecedent that drives and enhances digital transformation capability.

2.1.6. Critical review of prior research on R&D innovation cooperation

While existing literature consistently highlights the positive effects of R&D cooperation, several critical limitations remain unaddressed. First, most studies establish R&D cooperation as an independent variable and focus exclusively on its direct effect on innovation performance. Consequently, they lack theoretical explanatory power regarding the intermediate organizational capabilities through which cooperation translates into innovation. Second, prior research fails to fully capture organizational capabilities in the era of digital transformation. Despite the reality that digital-driven organizational change has emerged as a more critical factor for corporate innovation than mere technical development, studies incorporating digital transformation capability remain highly limited. Third, existing research has predominantly focused on manufacturing firms, thereby failing to reflect the unique characteristics of service enterprises. Even though digital platforms and customer experience innovation are core competitive drivers for service firms, SEM-based research targeting the service sector is still insufficient.

To overcome these limitations, this study investigates the impact of R&D innovation cooperation on corporate innovation by focusing not only on the direct effect but also on the mediating mechanism of digital transformation capability. This approach distinguishes itself from previous literature by integrating open innovation theory, the RBV, and dynamic capability theory to systematically explicate the inner mechanism linking R&D innovation cooperation to corporate innovation.

2.1.7. Inconsistent empirical findings and research gap

Although the majority of previous studies have reported that R&D innovation cooperation contributes positively to corporate innovation, the empirical evidence has not been entirely consistent. While several studies have demonstrated significant positive relationships between external R&D collaboration and innovation performance (Powell et al., 1996; Belderbos et al., 2004; Laursen & Salter, 2006), other studies have found that the effects of cooperation are relatively weak, context-dependent, or even statistically insignificant after controlling for firm-specific characteristics and organizational capabilities. These inconsistent findings suggest that external collaboration alone does not automatically translate into superior innovation outcomes.

One major explanation proposed in recent innovation literature is that firms differ substantially in their ability to absorb, integrate, and exploit externally acquired knowledge. Although R&D cooperation enables firms to access diverse technological resources and market knowledge, these external resources generate innovation only when they are effectively embedded into internal organizational processes. Firms lacking sufficient organizational capabilities often experience coordination difficulties, knowledge integration problems, and inefficient utilization of externally acquired technologies, thereby reducing the innovation benefits of collaborative R&D activities.

Recent studies on digital transformation further suggest that digital capabilities may explain these heterogeneous empirical findings. Digital technologies facilitate real-time knowledge sharing, data integration, organizational learning, and cross-functional collaboration, allowing firms to transform externally acquired knowledge into new products, services, and business models. Consequently, firms possessing strong digital transformation capability are more likely to realize innovation benefits from R&D cooperation than firms with weaker digital capabilities.

Despite these theoretical arguments, previous empirical studies have rarely incorporated digital transformation capability as an explicit mediating mechanism linking R&D innovation cooperation and corporate innovation. Most existing research has examined digital transformation either as an independent determinant of innovation or as an environmental condition rather than as an internal organizational capability that explains why similar levels of R&D cooperation produce different innovation outcomes. Therefore, the inconsistent empirical findings reported in previous studies reveal an important theoretical gap. This study addresses this gap by proposing and empirically validating digital transformation capability as the organizational mechanism through which R&D innovation cooperation is translated into corporate innovation within service enterprises.

2.2. Digital transformation capability

2.2.1. Concept of digital transformation capability

Digital transformation (DT) has emerged as one of the most prominent research topics in the field of corporate innovation. While initially conceptualized in a narrow sense to mean the adoption of information technology (IT) or the computerization of business tasks, it has evolved into a comprehensive concept that entails innovating corporate strategies, organizational structures, operational processes, customer relations, and business models based on digital technologies. Notably, recent academic literature shifts its focus away from digital technology itself toward digital transformation capability. Although digital technologies are general-purpose resources accessible to most firms, variation in innovation performance persists among firms using identical technologies. This divergence arises not from the technology itself, but from differences in the organizational capability to effectively integrate and leverage technology within

the value-creation process.

Warner and Wäger (2019) defined digital transformation capability as ‘a dynamic organizational capability that enables a firm to utilize digital technologies to continuously reconfigure its resources and processes, thereby generating a new competitive advantage in a rapidly changing digital environment’. Similarly, Vial (2019) described digital transformation as ‘a process that triggers significant changes to an entity’s properties through combinations of information, computing, communication, and connectivity technologies to improve its entities’. These definitions underscore that digital transformation is an organization-wide innovative capability rather than a mere technical implementation.

The importance of digital transformation capability is particularly amplified within service enterprises. Because service firms exhibit higher frequencies of customer interaction and deliver intangible offerings compared to manufacturing firms, data-driven customer management, platform services, AI-based customized offerings, and digital channel operations become core determinants of corporate competitiveness. Hence, digital transformation capability can be understood as a strategic organizational capability that accelerates service innovation. In this study, digital transformation capability is defined as an organization-level dynamic capability that enables a firm to leverage digital technologies to innovate its R&D, decision-making, operational processes, and customer value-creation mechanisms, ultimately securing a sustainable competitive advantage.

2.2.2. Characteristics of digital transformation capability

DT capability possesses several unique attributes that distinguish it from conventional IT utilization proficiency. First is strategic integration. Rather than being confined to the computerization of a specific department, digital transformation is an enterprise-wide activity that fuses corporate strategy with overall organizational innovation. Consequently, the digital leadership of top management and the strategic alignment of the entire organization serve as critical success factors. Second is dynamic adaptability. Given the breakneck speed of technological advancements, firms must continuously learn new digital technologies and reconfigure existing resources. This capacity for continuous adaptation is a core pillar of DT capability. Third is data-driven decision-making. Firms with high digital transformation capability can gather and analyze diverse data streams in real time, thereby enabling more precise, objective, and agile decision-making. Fourth is organizational learning. Digital technology facilitates knowledge sharing and collaboration among organizational members, fostering a culture of continuous learning. Thus, digital transformation acts as a catalyst that simultaneously drives both technical innovation and organizational learning. Fifth is innovation orientation. Moving beyond mere operational efficiency or cost-reduction, digital transformation capability actively stimulates innovative activities aimed at creating entirely new products, services, and business models.

2.2.3. Construct components of digital transformation capability

Recent literature conceptualizes digital transformation capability as a multidimensional organizational competence comprising several sub-dimensions. First, digital infrastructure capability refers to the foundational capacity to deploy and leverage digital technologies such as cloud computing, IoT, AI, and big data platforms. Second, digital process capability entails the ability to digitalize workflows and seamlessly facilitate information sharing across different organizational units. Third, digital innovation capability is defined as the capability to develop novel products and services by capitalizing on digital technologies. Fourth, data analytics capability denotes the capacity to analyze heterogeneous datasets to drive strategic decision-making. Fifth, digital organizational culture represents an environment in which organizational members

actively embrace digital tools and remain receptive to technology-driven change. These components interact complementarily to shape a firm's overall digital transformation capability.

Although digital transformation capability is conceptualized as a higher-order organizational capability in this study, its constituent dimensions may not be equally influenced by R&D innovation cooperation. Collaborative R&D activities provide firms with opportunities to access external technological knowledge, managerial expertise, and digital resources, which may strengthen specific dimensions of digital capability through different mechanisms. For example, cooperation with technology partners may primarily facilitate the development of digital infrastructure by accelerating the adoption of advanced digital technologies and cloud-based systems. Collaboration with universities and research institutes may enhance data analytics capability by improving firms' ability to collect, integrate, and analyze large volumes of data for innovation-related decision-making. Likewise, continuous interaction with diverse innovation partners may foster a digital organizational culture that encourages knowledge sharing, organizational learning, and openness to technological change.

These heterogeneous effects suggest that digital transformation capability should not merely be regarded as a homogeneous organizational resource but rather as a multidimensional capability whose individual components may respond differently to external collaboration. Nevertheless, because the primary objective of the present study is to examine the overall organizational mechanism linking R&D innovation cooperation and corporate innovation, digital transformation capability is modeled as an integrated higher-order construct. This approach is consistent with previous studies that conceptualize digital transformation as a comprehensive organizational capability encompassing multiple interrelated digital competencies.

2.2.4. Theoretical foundations of digital transformation capability

Digital transformation capability can be theoretically substantiated through the RBV, dynamic capability theory, and IT capability theory. Under the RBV, digital transformation capability is viewed as a valuable, rare, and inimitable intangible asset. The variance in performance among firms implementing identical digital systems occurs because firms possess differing levels of organizational capability to deploy those technologies effectively.

Dynamic capability theory explains digital transformation capability as a core competence for continuously reconfiguring existing asset bases in response to shifting environmental landscapes. Teece (2007) conceptualized dynamic capabilities into three clusters: sensing (identifying opportunities and threats), seizing (mobilizing resources to capture value), and transforming/aligning (continuous renewal of organizational structures). Digital transformation serves as a prime manifestation of these three processes being actualized throughout an enterprise.

Furthermore, IT capability theory posits that rather than the information technology itself, the capability to effectively align IT with corporate strategy and operations determines firm performance. In recent scholarship, the traditional notion of IT capability has expanded into digital transformation capability, evolving into a primary theoretical framework for explaining systemic organizational innovation and corporate performance in the digital economy.

2.2.5. Prior empirical research on digital transformation capability

Recent empirical studies consistently report that DT capability is a pivotal driver of corporate innovation and firm performance. Warner and Wäger (2019) argued that digital transformation capabilities enhance organizational agility and stimulate superior innovation performance. Vial (2019) elucidated that digital

transformation is not merely technical adoption, but a strategic innovation that restructures an organization's overarching value-creation mechanisms. Verhoef et al. (2021) further indicated that digital transformation is a holistic process wherein organizational culture, digital leadership, digital platforms, and data-driven decision-making operate interactively, and that these combined capabilities ultimately determine the success of corporate innovation.

Concurrently, recent literature focusing on service firms demonstrates that digital transformation capability exerts a positive influence on service innovation, customer satisfaction, operational efficiency, and firm performance. In particular, enterprises that actively leverage AI and big data report accelerated new product development cycles and higher levels of service innovation. In domestic research, digital transformation capability has also been presented as a core factor accelerating smart factory implementations, platform-based service development, and business model innovation, thereby exerting a substantial impact on the sustainable growth of enterprises.

2.3. Corporate innovation

2.3.1. Concept of corporate innovation

Corporate innovation refers to a series of innovative activities in which a firm develops novel products, services, production processes, organizational structures, and business models, or reconfigures existing resources and capabilities, to secure a sustainable competitive advantage in response to a rapidly changing business environment. Innovation is not confined merely to technical development or R&D outcomes; rather, it is understood as a core managerial activity that drives sustainable growth by reshaping a firm's value-creation mechanisms and delivering novel value to customers.

The most authoritative definition of innovation traces back to the innovation theory of Schumpeter (1934). Schumpeter categorized innovation into five distinct forms: the introduction of a new good, the introduction of a new method of production, the opening of a new market, the conquest of a new source of supply of raw materials, and the carrying out of the new organization of any industry. He asserted that the continuous growth of an enterprise is achieved through innovation, positioning it as the primary engine of economic development.

Since then, the conceptualization of innovation has expanded from a narrow focus on technological innovation to a broader scope encompassing organization-wide change and value creation. The OECD's Oslo Manual defines corporate innovation as the successful implementation of a new or significantly improved product, service, process, marketing method, or organizational method, explaining that the ultimate objectives of innovation lie in improving productivity, amplifying customer value, and enhancing firm performance.

In the contemporary digital economy, the scope of corporate innovation has expanded beyond traditional product and process innovation. Emerging technologies, including artificial intelligence, big data analytics, cloud computing, the internet of things, and digital platforms, have generated new forms of innovation such as digital business model innovation, platform innovation, customer experience innovation, digitally enabled service innovation, and data-driven innovation. These forms represent contemporary manifestations of corporate innovation and demonstrate how digital technologies broaden the ways in which firms create and deliver value.

However, the broader theoretical scope of corporate innovation should be distinguished from the operationalization adopted in the present study. For empirical consistency and parsimony, this study operationalizes corporate innovation as a four-dimensional construct comprising product/service innovation, process innovation, organizational innovation, and market-oriented innovation.

Accordingly, digital innovation, platform innovation, customer experience innovation, and digital business model innovation are treated as contemporary examples of innovation outcomes that fall within the broader conceptual domain of corporate innovation, rather than as separate measurement dimensions in the present empirical model.

This distinction enables the study to recognize the evolving nature of corporate innovation while maintaining a clear correspondence between the theoretical construct, its operational definition, the measurement instruments, and the empirical analysis.

2.3.2. Characteristics of corporate innovation

Corporate innovation possesses several distinct characteristics. First is continuity. Innovation is not a one-off episodic project but a long-term, continuous process achieved through ongoing organizational learning and iterative improvement. Firms that engage in continuous innovative activities exhibit higher adaptability to environmental shifts and are more likely to secure long-term competitive advantages. Second is value creation. The ultimate objective of innovation resides in generating new customer value. Consequently, innovation is evaluated based on the enhancement of value delivered to customers rather than the technical development itself. Third is uncertainty. Innovation inherently entails high levels of both technological and market uncertainty. Therefore, innovative activities are accompanied by the risk of failure, which demands strategic organizational capabilities to manage effectively. Fourth is integration. Innovation is not an isolated activity restricted to the R&D department; rather, it is an enterprise-wide activity wherein production, marketing, information technology, human resource management, and top management's strategic decision-making operate interactively and synthetically. Fifth is its dynamic nature. Innovation is an evolving process that responds continuously to shifting external conditions, characterized by the perpetual reconfiguration of organizational capabilities to adapt to emerging technological and market landscapes.

2.3.3. Construct components of corporate innovation

Corporate innovation is commonly conceptualized as a multidimensional construct that reflects a firm's capacity to introduce new or significantly improved products, services, processes, organizational practices, and market approaches. Consistent with the innovation literature and the operational requirements of the present study, corporate innovation is conceptualized here through four dimensions: product/service innovation, process innovation, organizational innovation, and market-oriented innovation.

First, product/service innovation refers to the development of new products or services or the substantial improvement of existing products or services in terms of quality, functionality, performance, or customer value. In service enterprises, this dimension encompasses the introduction of new service offerings and meaningful improvements in existing service propositions. Second, process innovation refers to the implementation of new or substantially improved methods of producing, delivering, or managing products and services, including improvements intended to increase efficiency, reduce costs, enhance quality, or improve service delivery. Third, organizational innovation refers to changes in organizational structures, managerial practices, decision-making processes, work arrangements, or organizational systems that improve the firm's ability to operate and innovate. Fourth, market-oriented innovation refers to the development or implementation of new approaches to markets, customer relationships, distribution channels, positioning, or value delivery that enable firms to respond more effectively to changing customer needs and market conditions.

The digital transformation of the business environment has expanded the ways in which these four dimensions can be implemented. Digital technologies such as artificial intelligence, big data analytics, cloud computing, the internet of things, and digital platforms can facilitate new service offerings, redesigned processes, organizational transformation, and new approaches to customer and market engagement. Accordingly, contemporary forms such as digital innovation, platform-based service innovation, customer experience innovation, and digital business model innovation can be understood as technology-enabled manifestations of the four dimensions identified above rather than as additional dimensions of the Corporate Innovation construct examined in this study.

For example, a digitally enabled new service represents product/service innovation, whereas the digital redesign of service delivery processes represents process innovation. The adoption of digital technologies to restructure organizational activities represents organizational innovation, while the use of digital platforms or data-driven customer engagement to develop new market approaches represents market-oriented innovation. Thus, digital technologies constitute important enablers and contexts of corporate innovation, but they do not constitute separate measurement dimensions in the present study.

Therefore, to maintain conceptual and empirical consistency, corporate innovation in this study is operationalized exclusively through four dimensions: product/service innovation, process innovation, organizational innovation, and market-oriented innovation. This four-dimensional operationalization is consistently reflected in the measurement instrument, confirmatory factor analysis, reliability and validity assessments, and subsequent structural model analysis. The broader digital forms of innovation discussed above are consequently treated as contemporary manifestations through which the four dimensions may be expressed, rather than as additional latent dimensions of corporate innovation.

2.3.4. Theoretical foundations of corporate innovation

This study utilizes the RBV, dynamic capability theory, and open innovation theory as the foundational theoretical frameworks to explain corporate innovation. The RBV posits that valuable, rare, and inimitable resources owned by a firm generate a sustainable competitive advantage. In the modern business environment, however, the capacity to effectively leverage external assets and convert them into new organizational competences is also deemed a vital strategic resource. Dynamic capability theory explains that a firm's capacity to continuously integrate, reconfigure, and deploy existing resource bases in rapidly shifting environments determines its ultimate corporate innovation. Particularly in the digital economy, the ability to align digital tools with organizational innovative activities is evaluated as a core element of corporate innovation rather than the technology itself. Furthermore, open innovation theory asserts that the process of connecting the knowledge and technology acquired via collaboration with external organizations to internal innovative activities dictates innovation outcomes. Consequently, R&D innovation cooperation can be understood as an essential antecedent of corporate innovation.

2.3.5. Prior empirical research on corporate innovation

Corporate innovation has been extensively investigated as one of the most critical variables explaining overall firm performance. Schumpeter (1934) maintained that innovation serves as the primary fountainhead that enables the continuous growth of an enterprise. Subsequently, Damanpour (1991) demonstrated that organizational innovation is a crucial strategic activity that enhances a firm's competitive advantage and organizational performance. The OECD (2018) reported that firms actively engaging in innovative activities exhibit substantial gains in productivity, market share expansion, and profitability. In

recent scholarship, the determinants of corporate innovation have been diversely analyzed in tandem with the advancement of digital technologies. In particular, R&D investment, open innovation, digital transformation, organizational learning, absorptive capacity, and dynamic capabilities have been advanced as pivotal variables explaining corporate innovation.

Concurrently, empirical research focusing on service firms indicates that higher levels of digital platform deployment, data-driven decision-making, and AI utilization lead to enhanced corporate innovation. In this context, digital transformation is consistently documented as a core driver that facilitates service innovation and customer value creation.

2.4. Theoretical background

To investigate the mediating effect of digital transformation capability on the relationship between R&D innovation cooperation and corporate innovation, this study integrates the RBV, dynamic capability theory, and open innovation theory into a cohesive theoretical framework. These three theories respectively explain the characteristics of resources that generate a competitive advantage, the significance of capabilities in adapting to shifting environments, and the innovation mechanisms leveraging external knowledge and technologies. Especially in the contemporary digital economy, these theoretical perspectives function complementarily to systematically elucidate the multi-stage process of corporate innovation.

2.4.1. Resource-based view (RBV)

The RBV is a prominent strategic management theory positing that a firm's sustainable competitive advantage stems from the strategic resources possessed within the firm rather than external industry structures. Wernerfelt (1984) defined a firm as a broader bundle of resources, arguing that performance variance across firms arises from differences in their resource configurations. Subsequently, Barney (1991) asserted that strategic resources driving a sustainable competitive advantage must simultaneously fulfill four criteria: value, rarity, inimitability, and non-substitutability, a framework widely recognized today as the VRIN framework.

From the lens of the RBV, R&D and innovative capabilities correspond to representative intangible resources. The technological knowledge, patents, know-how, and organizational learning accumulated through R&D are evaluated as critical strategic assets that competing firms cannot easily replicate. However, given the rapid mutations in today's technological landscape, sustaining a competitive edge solely through internal resources has become increasingly challenging, thereby magnifying the strategic importance of leveraging external resources. In this regard, R&D innovation cooperation can be understood as an essential resource-acquisition mechanism through which a firm secures external technologies and knowledge assets. By collaborating with universities, research institutes, customers, and suppliers, firms can obtain specialized expertise and innovative technologies that are difficult to develop independently, accumulating this external knowledge as a new strategic resource base.

Nevertheless, the RBV notes that merely acquiring external resources does not automatically guarantee a competitive advantage. A competitive advantage materializes only when the secured assets are effectively deployed within the firm and converted into new value. From this perspective, digital transformation capability can be conceptualized as an intangible strategic asset that converts externally acquired technology and knowledge into internal innovation capabilities. Because basic digital technologies are general-purpose tools readily accessible to most firms, the technology itself rarely possesses rarity. Conversely, the capability to synthesize and utilize digital technologies with organizational culture,

business workflows, and corporate strategy varies substantially across enterprises, evolving into a deeply embedded organizational capability that is highly resistant to imitation. Therefore, digital transformation capability satisfies the criteria of a strategic core resource as delineated by the RBV.

Ultimately, corporate innovation manifests as an outcome variable reflecting how effectively these strategic resources are utilized within the enterprise. Hence, the RBV provides the fundamental theoretical foundation for explaining the structural pathway proposed in this study: R&D innovation cooperation → digital transformation capability → corporate innovation.

2.4.2. Dynamic capability theory

While the resource-based view emphasizes the significance of a firm's possessed resource base, dynamic capability theory focuses on an organization's capacity to continuously reconfigure its resources and generate a new competitive advantage amid a shifting environment. Teece et al. (1997) defined dynamic capabilities as a firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments. Subsequently, Teece (2007) conceptualized dynamic capabilities into three clusters of core microfoundations. The first is sensing, which denotes the capacity to identify and assess opportunities and technological mutations. The second is seizing, which entails the capability to mobilize resources to address opportunities and capture value through corporate strategy and investments. The third is transforming (or managing threats and reconfiguration), which involves the continuous renewal and alignment of organizational structures and asset bases to sustain a competitive edge.

The significance of these dynamic capabilities is exponentially magnified within the contemporary digital economy. Because digital technologies—such as artificial intelligence, big data, and cloud computing—evolve at a breakneck pace, firms must continuously internalize novel technologies and drive organization-wide metamorphosis. In the context of this study, R&D innovation cooperation corresponds to the sensing stage, wherein firms actively explore new technological opportunities and scan for strategic alternatives. Through collaboration with external entities, enterprises systematically acquire cutting-edge technological information and innovative insights.

Conversely, digital transformation capability aligns with the transforming stage, representing the process of deploying the newly secured technologies into internal business workflows, processes, and business models. The process of deeply embedding digital tools across the enterprise and constructing data-driven decision-making architectures can be viewed as a quintessential asset-reconfiguration activity. Ultimately, corporate innovation manifests as the direct outcome of these dynamic capabilities being successfully translated into actual innovative performance. Therefore, dynamic capability theory effectively substantiates that digital transformation capability is not merely an operational IT utility, but a core dynamic organizational competence that bridges external knowledge assets to systematic corporate innovation.

2.4.3. Open innovation theory

The most pronounced paradigm shift in the contemporary R&D landscape is that innovative activities are transitioning from internally centralized frameworks to externally cooperative networks. Chesbrough (2003) pioneered the concept of open innovation to explicate this phenomenon, asserting that firms should actively capitalize on a wide array of external ideas and technologies in tandem with internal R&D pathways to accelerate corporate innovation. Conventional closed innovation models operated on the premise that the entire lifecycle—from initial basic research to commercialization—must be executed within the

boundaries of a single firm. However, as technological complexity escalates and R&D costs surge exponentially, relying solely on internal capabilities has become structurally unsustainable. Consequently, modern enterprises actively engage with a diverse constellation of external innovation actors—including universities, research institutes, startups, customers, and suppliers—to co-develop novel technologies.

Open innovation theory posits that these collaborative networks serve as the primary locomotive for amplifying innovation performance. Nonetheless, recent scholarship emphasizes that the mere acquisition of external knowledge does not automatically guarantee innovative success. For external knowledge assets to culminate in the development of novel products and services, they must first be absorbed into the firm and synergized with digital-driven operational workflows. Within this framework, digital transformation capability can be conceptualized as the core organizational architecture that maximizes the efficacy of open innovation initiatives.

Particularly within service enterprises, there is a prominent surge in platform-mediated customer co-creation, data-driven service innovation, and AI-powered product development. Empirically, these innovative endeavors yield substantial performance dividends only when external collaboration and internal digital transformation occur simultaneously. In sum, open innovation theory provides a robust theoretical rationale for the multi-stage conceptual path of this research, wherein R&D innovation cooperation enhances digital transformation capability, which in turn catalyzes corporate innovation.

2.4.4. Comprehensive integration of the three theories

The RBV, dynamic capability theory, and open innovation theory applied in this study are not mutually exclusive conceptual frameworks, but rather form a highly complementary relationship. First, open innovation theory explicates the systematic process through which a firm acquires novel technologies and knowledge assets via external R&D collaboration—thereby establishing the core mechanism for external resource acquisition. Second, the RBV explains the conditions under which these secured external knowledge bases are accumulated as strategic resources to generate a sustainable competitive advantage—thereby illuminating the strategic value of the resources. Third, dynamic capability theory delineates the process of combining these strategic assets with digital technologies to transform them into organization-wide innovative competences—thereby expounding the resource mobilization and reconfiguration mechanism.

Ultimately, corporate innovation is not dictated solely by external collaboration itself, but materializes during the process of converting externally acquired knowledge into digital-driven organizational capabilities. Consequently, digital transformation capability plays a crucial mediating role in bridging external innovation collaboration and corporate innovation. This integrated theoretical framework addresses the limitations of prior research, which predominantly focused on direct effects, and theoretically substantiates the multi-stage research model proposed in this study: R&D innovation cooperation → digital transformation capability → corporate innovation. Especially in the contemporary digital economy, a firm's sustainable competitive advantage is determined by its capacity to transform collaborative knowledge assets into digital-based organizational capabilities and translate them into continuous innovation; in this regard, the theoretical framework of this study possesses robust explanatory power.

2.5. Relationships between variables and research hypotheses

Grounded in an integrated theoretical framework encompassing the RBV, dynamic capability theory, and open innovation theory, this study aims to examine

the mediating effect of digital transformation capability on the relationship between R&D innovation cooperation and corporate innovation. While prior literature consistently reports that R&D innovation cooperation exerts a positive influence on corporate innovation, empirical research addressing the internal organizational capabilities through which collaboration translates into systemic innovation has remained relatively scarce. In particular, SEM-based research establishing digital transformation capability as a mediator within the digital economy landscape is highly limited. Therefore, this study theoretically reviews the causal relationships among the variables and develops the following research hypotheses.

2.5.1. Relationship between R&D innovation cooperation and digital transformation capability

Enterprises are continually expanding R&D collaboration with external organizations to effectively address rapid technological mutations and the volatile landscape of the digital economy. Collaboration with universities, research institutes, suppliers, customers, and startups does not merely entail securing novel technologies; rather, it functions as an essential organizational learning mechanism that enhances a firm's digital innovative capabilities. According to open innovation theory, firms acquire heterogeneous knowledge and technologies through collaboration with diverse external innovation actors, and this external knowledge serves as a core resource pool that elevates internal innovation capacities (Chesbrough, 2003). Given the breakneck velocity at which digital technologies evolve, relying strictly on internal R&D pathways makes it structurally challenging to secure cutting-edge technical expertise. Consequently, continuous R&D collaboration with external entities is conceptualized as an indispensable strategy that drives the adoption and deployment of advanced digital applications.

Similarly, dynamic capability theory posits that firms secure a sustainable competitive advantage by systematically navigating a multi-stage process: identifying new technological opportunities from the external environment (sensing) and subsequently restructuring their internal asset bases (transforming) (Teece, 2007). R&D cooperation represents a quintessential sensing activity, and the digital technologies alongside innovative insights harvested during this cooperative process supply the vital raw resources necessary to trigger enterprise-wide digital transformation.

Prior empirical literature further corroborates that R&D collaboration exerts a significant positive influence on technology adoption and organizational renewal. Warner and Wäger (2019) documented that firms embedded in active external collaborative networks possess superior digital transformation capabilities and exhibit accelerated paces of strategic renewal. Verhoef et al. (2021) also illuminated that open, collaborative alliances facilitate the construction of sophisticated digital platforms and stimulate data-driven decision-making systems.

Within service enterprises, this systemic relationship is profoundly amplified. Because service firms generate economic value primarily based on real-time customer interactions, the digital assets and knowledge secured through external alliances can be immediately mobilized to drive service innovation and enhance customer experiences. Taken together, R&D innovation cooperation can be understood as a critical antecedent that actively develops and reinforces a firm's digital transformation capability. Recent empirical studies on service enterprises further suggest that collaborative R&D plays an essential role in strengthening firms' digital capabilities by facilitating the adoption of digital platforms, cloud-based technologies, AI applications, and customer-oriented digital services. Because service firms rely heavily on knowledge integration

and digital interaction rather than physical production assets, collaborative innovation enables them to accelerate digital capability development through continuous knowledge exchange and technology sharing. These findings provide additional empirical support for the positive relationship between R&D innovation cooperation and digital transformation capability in service industries. Grounded in this rationale, the following research hypothesis is proposed: H1: R&D innovation cooperation will have a significant positive (+) effect on digital transformation capability.

2.5.2. Relationship between digital transformation capability and corporate innovation

Digital technologies are fundamentally reshaping not only corporate R&D methods but also the overarching organizational operations and value-creation mechanisms of modern enterprises. However, even when implementing identical digital architectures, substantial variations in innovation performance persist across firms. This divergence highlights that the true source of competitive differentiation resides not in the digital technology itself, but in the internal organizational capability to strategically deploy and align those digital assets. Under the RBV, digital transformation capability is conceptualized as an intangible, strategic organizational asset that is deeply embedded, historically accumulated, and highly resistant to imitation by competing firms. By capitalizing on digital transformation capabilities, enterprises can systematically restructure operational workflows, extract actionable insights from big data analytics, and engineer novel business models, thereby securing a sustainable competitive advantage.

Concurrently, dynamic capability theory explains digital transformation capability as a core competence that reconfigures existing asset bases to orchestrate a new competitive advantage amid turbulent environmental shifts (Teece, 2007). In particular, advanced digital infrastructures—such as artificial intelligence, big data, and cloud computing—serve as the foundational architecture that accelerates organizational decision-making speed, objective precision, and the overall efficiency of innovative endeavors.

Extensive prior empirical research underscores that digital transformation capability exerts a robust positive influence across multiple dimensions of innovation, including product, process, organizational, and service innovation. Warner and Wäger (2019) demonstrated that digital transformation capabilities substantially amplify organizational agility and catalyze superior innovative performance. Vial (2019) further elucidated that digital transformation is a strategic, structural innovation that redefines an entity's value-creation mechanisms, positioning it as a primary antecedent of corporate innovation. Furthermore, Verhoef et al. (2021) analyzed that firms equipped with robust digital transformation capabilities achieve faster time-to-market cycles for new products and services, alongside superior levels of customer value creation. Recent literature focusing on the service sector similarly reports that enterprises actively utilizing digital platforms and data-driven decision-making systems achieve pronounced gains in their overall innovative outcomes.

Synthesizing these theoretical arguments and empirical findings, digital transformation capability can be understood as a core organizational competence that directly drives corporate innovation. In service industries, digital transformation capability has been identified as a major driver of innovation performance because it enables firms to redesign service delivery processes, improve customer experience, and develop platform-based business models. Recent empirical studies have shown that service firms with stronger digital capabilities achieve superior innovation outcomes through data-driven

decision-making, personalized service provision, and digital ecosystem participation. These findings reinforce the expectation that digital transformation capability positively influences corporate innovation in service enterprises. Accordingly, the following research hypothesis is proposed: H2: digital transformation capability will have a significant positive (+) effect on corporate innovation.

2.5.3. Relationship between r&d innovation cooperation and corporate innovation

R&D innovation cooperation stands as one of the most prominent antecedents explaining corporate innovation. Open innovation theory posits that continuous collaboration with external organizations serves as a core mechanism for enhancing a firm's innovation performance. Through external alliances, enterprises can secure state-of-the-art technological and market information, disperse R&D costs and associated risks, and capitalize on a diverse spectrum of specialized expertise. This collaboration effectively drives not only the development of novel products and services but also organizational and business model innovation.

Belderbos et al. (2004) demonstrated that R&D cooperation with universities, customers, and suppliers exerts a significant positive influence on both product and process innovation. Similarly, Laursen and Salter (2006) analyzed that firms embedded in broader external collaborative networks achieve superior innovative performance. Powell et al. (1996) further elucidated that inter-firm cooperative networks play a vital role in creating novel technological knowledge and upgrading internal innovation capabilities.

Concurrently, recent empirical research focusing on domestic and international service enterprises consistently validates that R&D innovation cooperation is a primary driver of corporate innovation and business performance. In particular, within service firms leveraging digital applications, external collaboration actively accelerates service innovation and customer value creation. However, some literature suggests that the ultimate efficacy of R&D cooperation may heavily depend on the firm's internal organizational capacity. That is, rather than the mere act of collaboration itself, the capability to effectively manage and deploy those alliances can be the primary determinant of corporate innovation. Nevertheless, R&D innovation cooperation remains widely recognized as a critical antecedent that directly shapes corporate innovation. Previous empirical studies on service innovation have also demonstrated that collaborative R&D contributes directly to service innovation by expanding access to external knowledge, enhancing customer-oriented innovation, and facilitating the development of new digital services. Service enterprises benefit particularly from cooperation with universities, technology providers, and business partners because these collaborations enable rapid adaptation to changing customer needs and digital market environments. Accordingly, collaborative R&D is expected to positively influence corporate innovation in service enterprises. Grounded in this rationale, the following research hypothesis is developed: H3: R&D innovation cooperation will have a significant positive (+) effect on corporate innovation.

2.5.4. Mediating effect of digital transformation capability

In recent innovation literature, a growing body of research highlights that various organizational capabilities function as crucial mediating mechanisms between external collaboration and innovation performance. Construct variables such as absorptive capacity, organizational learning, innovation capability, and dynamic capabilities have been widely advanced as core pathways through which external resources are successfully translated into firm performance. Digital transformation capability can be conceptualized as a vital modern

extension of these organizational competences. The heterogeneous technologies and information acquired via R&D innovation cooperation can culminate in systemic innovation performance only when successfully integrated into internal digital systems and operational workflows.

Under the RBV, externally secured technologies require robust organizational capabilities to be effectively mobilized as strategic assets capable of generating a sustainable competitive advantage. Dynamic capability theory similarly asserts that the continuous reconfiguration of assets harvested from the external environment represents the definitive engine of corporate innovation. Recent prominent studies by Warner and Wäger (2019), Verhoef et al. (2021), and Vial (2019) likewise present digital transformation capability as the core organizational architecture bridging external networks to innovation outcomes.

Firms equipped with robust digital transformation capabilities can rapidly align externally acquired technological knowledge with data-driven decision-making, digital platform deployment, and operational restructuring, thereby achieving higher levels of corporate innovation. Conversely, firms lacking digital transformation capabilities may fail to effectively deploy and internalize the technologies and insights secured through collaboration—even when engaging in identical levels of R&D alliances—which structurally limits their innovative output. Consequently, digital transformation capability is hypothesized to play an essential mediating role in the relationship between R&D innovation cooperation and corporate innovation. From the perspective of service innovation, digital transformation capability provides the organizational mechanisms through which externally acquired knowledge is transformed into customer value and innovation outcomes. Collaborative R&D supplies valuable external resources, while digital capabilities enable service firms to integrate, analyze, and apply these resources in developing innovative services and business models. Therefore, the mediating role of digital transformation capability is particularly relevant in service enterprises characterized by knowledge-intensive and digitally enabled innovation processes. Accordingly, the following research hypothesis is proposed: H4: digital transformation capability will significantly and positively (+) mediate the relationship between R&D innovation cooperation and corporate innovation.

2.5.5. Synthesis of the research model

Synthesizing the aforementioned prior empirical research and theoretical literature, R&D innovation cooperation constitutes an open innovation activity focused on securing novel technologies and knowledge assets through collaboration with diverse external innovation actors. Subsequently, this external knowledge is internalized, absorbed, and reconfigured within the enterprise through the mechanism of digital transformation capability. In turn, digital transformation capability accelerates data-driven decision-making, digital operational restructuring, and the engineering of novel business models, ultimately driving and enhancing overall corporate innovation.

Therefore, this study proposes a SEM framework establishing R&D innovation cooperation as the independent variable, corporate innovation as the dependent variable, and digital transformation capability as the mediating variable. The structural pathways and operational layout of this proposed research model will be delineated in detail in the subsequent methodology section.

3. Research methodology

3.1. Research model

The purpose of this study is to investigate the impact of R&D innovation cooperation on corporate innovation within service enterprises and to empirically test the mediating effect of digital transformation capability in this relationship. In contemporary business environments, corporate innovation is rarely achieved

simply by expanding external R&D collaboration; rather, the process of internalizing and converting the acquired technologies and knowledge assets into digital-based organizational capabilities has been increasingly recognized as paramount.

Accordingly, this study establishes a comprehensive research model grounded in the RBV, dynamic capability theory, and open innovation theory. Under the resource-based view, technologies and knowledge secured through external alliances are conceptualized as strategic resources. Concurrently, dynamic capability theory posits that the capacity to reconfigure these assets into new internal competences drives a sustainable competitive advantage. Furthermore, open innovation theory suggests that collaborative networks with external innovation actors serve as a primary mechanism for augmenting innovation performance.

Based on these integrated theoretical foundations, this study establishes R&D innovation cooperation as the independent variable, corporate innovation as the dependent variable, and digital transformation capability as the mediating variable. The structural framework and operational layout of the proposed research model are illustrated in **Figure 1**.

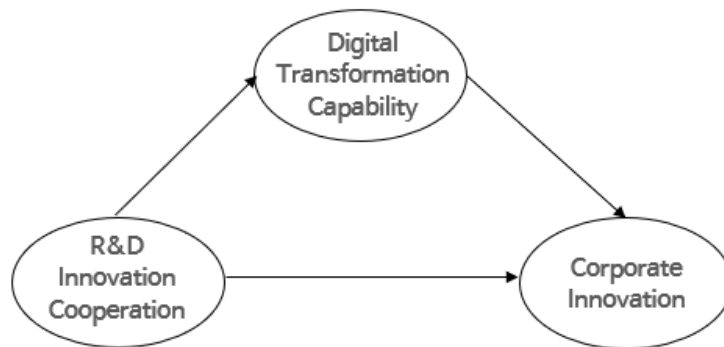


Figure 1. Research model

3.2. Operational definitions

An operational definition is the strategic process of conceptualizing abstract research constructs into empirically measurable indicators. For this study, measurement items whose reliability and validity have been rigorously verified in prior empirical literature were adapted and refined to align with the specific research objectives.

3.2.1. R&D innovation cooperation

R&D innovation cooperation refers to collaborative activities in which firms jointly perform R&D and share technologies and knowledge with a diverse array of external innovation actors to generate innovative performance. Chesbrough (2003), from an open innovation perspective, elucidated that firms maximize their innovative outcomes when they actively capitalize on external technologies and ideas through collaboration alongside internal R&D pathways. Furthermore, Belderbos et al. (2004) reported that R&D cooperation with universities, research institutes, suppliers, and customers is a core driver that facilitates both product and process innovation, while Laursen and Salter (2006) asserted that a broader scope of collaboration with heterogeneous innovation actors significantly improves a firm's innovation performance.

Grounded in these prior studies, this research operationally defines R&D innovation cooperation as the extent to which a firm conducts joint R&D projects, shares technological data and insights, and constructs continuous innovation networks with external entities, including universities, research

institutes, suppliers, customers, and government agencies. To measure this construct, a four-item scale was developed, evaluating the execution of joint R&D, real-time sharing of technological information, establishment of cooperative networks, and the degree of ongoing collaboration with external organizations.

3.2.2. Digital transformation capability

Digital transformation capability denotes an organization-level competence that enables a firm to effectively deploy digital technologies across the enterprise to innovate its operational processes, decision-making, and value-creation mechanisms. Vial (2019) conceptualized digital transformation as a strategic change process that leverages digital technologies to trigger significant structural alterations to an entity's properties and value-creation mechanisms. Warner and Wäger (2019) described digital transformation capability as a dynamic capability that allows a firm to continuously sense emerging technologies and reconfigure internal asset bases to secure a sustainable competitive advantage in highly turbulent digital landscapes. Moreover, Verhoef et al. (2021) advanced that digital transformation capability is a holistic organizational capacity wherein digital infrastructure, data-driven decision-making, organizational culture, and digital leadership operate interactively.

Reflecting these theoretical foundations, this study operationally defines digital transformation capability as an organization-level capacity that enables a firm to leverage advanced digital technologies to restructure operational workflows, execute data-driven decision-making, and generate novel business value. Measurement for this variable comprises four items assessing the intensity of digital technology utilization, implementation of data-driven decision-making, digital process innovation, and the fosterage of a digital organizational culture.

3.2.3. Corporate innovation

Corporate innovation signifies a series of innovative endeavors in which an enterprise develops novel products, services, production processes, organizational operations, and business models, or revamps existing resource bases to secure a sustainable competitive advantage. Schumpeter (1934) pioneered the conceptualization of innovation by classifying it into the development of new goods, the introduction of new methods of production, the opening of new markets, and the carrying out of new organizations of industries, while Damanpour (1991) defined corporate innovation as an organization-wide change activity implemented to optimize organizational performance. Additionally, the OECD/Eurostat (2018) Oslo Manual defines innovation as a new or improved product or process that differs significantly from previous products or processes and that has been made available to potential users or brought into use. Building upon these established frameworks, this study operationally defines corporate innovation as the systemic level of innovation through which a firm continuously enhances its products, services, operational processes, organizational structures, and market responsiveness to orchestrate a new competitive edge. The construct is measured via a four-item scale designed to evaluate product/service innovation, process innovation, organizational innovation, and market-oriented innovation.

3.3. Measurement instruments

The measurement items used in this study were adapted and refined from scales whose reliability and validity have been established in prior empirical literature. All items were evaluated using a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), as presented in **Table 1**.

Table 1. Measurement items and instruments

Variable	Number of questions	Key Measurements	Major prior research
R&D Innovation Cooperation	4	Collaborative research, technical cooperation, information sharing, collaborative networks	Chesbrough(2003), Belderbos et al.(2004), Laursen & Salter (2006)
Digital Transformation Capability	4	Digital utilization, data-driven decision-making, digital work innovation, digital organizational culture	Vial(2019), Warner & Wäger(2019), Verhoef et al.(2021)
Corporate Innovation	4	Product/service innovation, process innovation, organizational innovation, market-oriented innovation	Schumpeter(1934), OECD(2018), Damanpour(1991)

3.4. Data collection

To empirically test the structural relationships among R&D innovation cooperation, digital transformation capability, and corporate innovation, this study conducted a survey targeting service enterprises in South Korea. The survey respondents were strictly limited to individuals with a comprehensive understanding of their firms' innovation initiatives, such as CEOs, executives, department heads, and managers in companies actively engaging in R&D activities or digital transformation. Data collection was carried out over approximately one month, from April 1 to April 30, 2026, utilizing both online and offline survey channels simultaneously. Prior to distributing the questionnaire, the purpose and significance of the study were thoroughly explained, and voluntary participation was encouraged by informing participants that their responses would be used strictly for academic purposes and that complete anonymity would be guaranteed. Furthermore, in cases where multiple responses were received from a single enterprise, only the survey from the respondent who possessed the highest proficiency regarding the firm's R&D and digital transformation activities was retained for analysis.

A total of 350 questionnaires were distributed during the survey period. Of these, 328 questionnaires were returned, corresponding to a questionnaire response rate of 93.7% (328/350). After rigorous data screening, 305 valid questionnaires were retained for empirical analysis, resulting in an effective valid-response rate of 87.1% (305/350). During the data screening process, questionnaires with substantial omitted responses, insincere answers characterized by repetitive response patterns, excessive central-tendency responses, or statistical outliers were excluded. Missing values were also carefully inspected, and cases with unacceptable levels of missing data or potential bias were removed from further analysis.

Through this systematic screening process, a final sample of 305 valid questionnaires was retained for empirical analysis. This final sample size satisfies the minimum criteria required for SEM. Hair et al. (2022) posited that a minimum of 200 cases is generally required to apply SEM, and a sample size of 250 to 300 or more ensures stable parameter estimation and reliable model fit assessment. Kline (2023) similarly noted that a sample exceeding 200 cases is highly appropriate for SEM frameworks deploying the maximum likelihood estimation (MLE) method. Consequently, the 305 valid cases secured in this study were deemed fully sufficient to conduct confirmatory factor analysis (CFA), SEM, and bootstrapping-based mediation analyses.

To reduce the potential influence of common method bias (CMB), several procedural remedies were implemented during the survey design and data collection process. First, respondents were assured that all responses would remain anonymous and confidential and would be used solely for academic

research purposes. Second, participation in the survey was entirely voluntary, thereby reducing evaluation apprehension and encouraging honest responses. Third, questionnaire items representing different constructs were arranged in a randomized sequence to minimize respondents' ability to infer relationships among variables and to reduce response consistency bias. These procedural controls are consistent with the recommendations of Podsakoff et al. (2003) for mitigating common method bias in survey research. Harman's single-factor test was conducted to assess the potential influence of common method bias. The results showed that the first unrotated factor accounted for 35.292% of the total variance, which is below the commonly used 50% threshold. Therefore, common method bias does not appear to represent a serious threat to the validity of the empirical results.

The questionnaire items were adapted from previously validated measurement scales and were reviewed by experts in innovation management and service research to ensure content validity. Prior to the main survey, a pilot test was conducted to confirm the clarity and appropriateness of the questionnaire items. Respondents were selected from managers and employees who possessed sufficient knowledge of their firms' R&D cooperation activities and digital transformation initiatives. Participation was voluntary and anonymous, and all responses were treated confidentially for research purposes.

3.5. Data analysis method

In this study, statistical analyses were performed using SPSS Statistics 29.0 and AMOS 29.0 software. Given that this study aims to empirically validate a theoretically grounded research model and examine the hypothesized causal relationships among latent constructs, covariance-based structural equation modeling (CB-SEM) was selected. Compared with PLS-SEM, which is primarily oriented toward prediction and exploratory model development, CB-SEM is more suitable for confirmatory theory testing because it provides comprehensive model fit assessments. Accordingly, AMOS was used to estimate the measurement and structural models and to test the proposed mediation effects.

The exact sequential data analysis procedure is as follows: First, frequency and descriptive statistical analyses were conducted to examine the general demographic and institutional characteristics of the respondents and firms. Second, CFA was executed to verify the reliability and validity of the measurement model. Internal consistency and construct reliability were evaluated using Cronbach's α and composite reliability (CR). Convergent validity was assessed based on standardized factor loadings and average variance extracted (AVE) values. Third, discriminant validity among the latent constructs was examined utilizing the Fornell-Larcker criterion alongside the heterotrait-monotrait ratio (HTMT). Fourth, SEM was performed to evaluate the overall goodness-of-fit of the proposed research model and to test the hypothesized paths. Model fit evaluation comprehensively incorporated multiple indices, including χ^2 , χ^2/df , the comparative fit index (CFI), the Tucker-Lewis Index (TLI), the incremental fit index (IFI), the goodness of fit index (GFI), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR).

Fifth, the structural mediating effect of digital transformation capability was rigorously tested via bootstrapping with 5,000 resamples. The bootstrap analysis utilized a bias-corrected 95% confidence interval (CI); the indirect effect was determined to be statistically significant if the confidence interval did not include zero. Finally, by comparing the direct and indirect effects simultaneously, the model was evaluated to determine whether it exhibited full or partial mediation.

4. Research results and discussion

4.1. Descriptive statistics

The final sample consisted of 305 valid respondents. The respondents were individuals with direct knowledge of their firms' R&D innovation cooperation, digital transformation activities, and innovation performance, including CEOs, executives, department heads, and managers. In terms of respondent position, 168 respondents were CEOs or owners, representing 55.1% of the valid sample, while 46 were executives (15.1%), 45 were department heads (14.8%), and 46 were managers (15.1%). Thus, more than half of the respondents were CEOs or owners, while the remaining respondents were distributed relatively evenly across executive, department-head, and managerial positions.

Regarding firm characteristics, the sample included service enterprises of different sizes and across various service-sector categories. In terms of firm size, small firms accounted for 31.8% of the sample, medium-sized firms represented 34.4%, and large firms accounted for 33.8%. With respect to service-sector composition, business and professional services accounted for 36.1% of the sample, information and Information and Communications Technologies (ICT)-related services represented 32.5%, and other service industries accounted for 31.5%. Overall, the sample encompasses respondents with diverse organizational positions, firm sizes, and service-sector backgrounds, providing an appropriate empirical basis for examining the relationships among R&D innovation cooperation, digital transformation capability, and corporate innovation.

Prior to hypothesis testing via SEM, descriptive statistical analysis was conducted to examine the general characteristics of the data. The primary objective of the descriptive statistics is to determine the distributional properties of each latent variable by calculating the mean, standard deviation, skewness, and kurtosis, and to verify whether the data satisfies the assumption of univariate normality. Because structural equation modeling using the MLE method operates under the premise of multivariate normality, verifying that the empirical data adheres to a normal distribution is a prerequisite for robust estimation (Hair et al., 2022). In this study, descriptive statistics were performed using SPSS 29.0 to compute the mean and standard deviation for each latent construct. Concurrently, skewness and kurtosis indices were analyzed to confirm data normality. Generally, West et al. (1995) posited that an absolute value of skewness within ± 2.0 and an absolute value of kurtosis within ± 7.0 indicate no major issues in applying maximum likelihood estimation. Kline (2023) advanced a slightly more rigorous threshold, explaining that data is highly suitable for SEM analysis when the absolute value of skewness is 3.0 or less, and the absolute value of kurtosis is 10.0 or less.

The analytical results indicated that the means of all latent constructs exceeded the scale midpoint (3.00), implying that the responding service firms perceive their levels of R&D innovation cooperation, digital transformation capability, and corporate innovation relatively positively. In particular, the mean score for digital transformation capability was the highest, suggesting that service enterprises have recently been actively advancing the deployment of digital technologies and driving organization-wide digital shifts.

The standard deviations for all variables ranged between 0.60 and 0.80, confirming that the responses were not overly concentrated around specific values but exhibited an appropriate level of dispersion. This demonstrates that the dataset possesses sufficient variance required for structural equation modeling. The skewness values ranged from -0.64 to -0.18, and the kurtosis values ranged from -0.47 to 0.84. Because all construct metrics fell safely within the conservative thresholds established in prior methodological literature, the data utilized in this study was determined to successfully satisfy the assumption of normality. The

descriptive statistics for the latent variable are shown in **Table 2**.

Table 2. Descriptive statistics for latent variables

Variable	Average	Standard deviation	Minimum value	Maximum value	Skewness	Kurtosis
R&D Innovation Cooperation	3.82	0.71	1.56	5.00	-0.41	0.12
Digital Transformation Capability	3.94	0.66	1.73	5.00	-0.58	0.63
Corporate Innovation	3.87	0.69	1.60	5.00	-0.36	-0.18

The descriptive statistical analysis at the observed variable level similarly revealed that the mean scores for all individual measurement items exceeded 3.60, confirming that the respondents generally provided positive evaluations across all questionnaire items. The standard deviations for each item ranged from 0.60 to 0.90, demonstrating that an appropriate level of response variance was secured and no systemic response bias or extreme skew toward specific items was detected. Furthermore, the skewness values for the observed variables ranged from -0.90 to 0.15, and the kurtosis values ranged from -0.70 to 1.35. Because all measurement items fell well within the permitted thresholds for univariate normality, each individual item was determined to be fully appropriate for the application of the MLE method within the structural equation modeling framework. The descriptive statistics for observed variables are shown in **Table 3**.

Table 3. Descriptive statistics for observed variables (measurement items)

Latent variable	Questions	Average	Standard deviation	Skewness	Kurtosis
R&D Innovation Cooperation	1	3.81	0.76	-0.36	0.14
	2	3.86	0.73	-0.45	0.36
	3	3.78	0.71	-0.31	-0.24
	4	3.84	0.75	-0.42	0.19
Digital Transformation Capability	1	3.95	0.67	-0.69	0.84
	2	3.98	0.69	-0.71	0.93
	3	3.90	0.68	-0.54	0.41
	4	3.92	0.66	-0.49	0.22
Corporate Innovation	1	3.88	0.71	-0.35	-0.12
	2	3.84	0.69	-0.29	-0.18
	3	3.90	0.73	-0.43	0.16
	4	3.86	0.72	-0.38	0.09

Synthesizing the results of the descriptive statistical analysis, all variables in this study exhibit appropriate means and standard deviations, and the skewness and kurtosis indices fully satisfy the normality criteria required for structural equation modeling. Therefore, the empirical data secured in this study is determined to be highly suitable for executing CFA, structural model analysis, and mediation testing via bootstrapping. Furthermore, as sufficient variance across variables has been established and the distribution of response data remains stable, the reliability and validity tests, as well as the subsequent structural model analysis results, are expected to yield high credibility. Consequently, the next section details the confirmatory factor analysis alongside the evaluation of reliability and convergent validity to verify the adequacy of the measurement model.

4.2. Confirmatory factor analysis (CFA), reliability, and convergent validity verification

Prior to testing the structural relationships embedded in the research model, CFA was performed to assess the overall goodness-of-fit of the measurement model and to verify the reliability and validity of the measurement instruments. CFA is a rigorous statistical method used to test whether the pre-specified relationships between latent constructs and their respective observed indicators fit the empirical data adequately, serving as an indispensable prerequisite in structural equation modeling (Hair et al., 2022). In this study, AMOS 29.0 was utilized to apply the MLE method, concurrently analyzing the measurement model encompassing R&D innovation cooperation, digital transformation capability, and corporate innovation.

The goodness-of-fit of the measurement model was comprehensively evaluated using multiple fit indices, including χ^2 (Chi-square), χ^2/df , CFI, TLI, IFI, GFI, RMSEA, and SRMR. Generally, a model is evaluated to have an acceptable or good fit when $\chi^2/\text{df} \leq 3.0$; CFI, TLI, IFI, and GFI ≥ 0.90 ; and RMSEA and SRMR ≤ 0.08 (Hair et al., 2022; Kline, 2023). The CFA results indicated that the goodness-of-fit indices for the baseline measurement model were $\chi^2 = 83.462$ ($\text{df} = 51$, $p < 0.001$), $\chi^2/\text{df} = 1.637$, CFI = 0.979, TLI = 0.973, IFI = 0.979, GFI = 0.958, RMSEA = 0.046, and SRMR = 0.035. Although the χ^2 statistic was statistically significant due to its inherent sensitivity to sample size, the χ^2/df ratio fell safely below 2.0, and the CFI, TLI, IFI, and GFI values all substantially exceeded the recommended threshold of 0.90. Furthermore, the RMSEA and SRMR values were documented at 0.046 and 0.035, respectively, remaining well below the conservative cutoff value of 0.08. Consequently, the measurement model utilized in this study was determined to exhibit an overall excellent model fit.

4.2.1. Reliability verification

To assess the internal consistency of the measurement instruments, Cronbach's α and CR values were calculated. Generally, a measurement scale is deemed highly reliable when both Cronbach's α and CR values meet or exceed the threshold of 0.70 (Nunnally & Bernstein, 1994; Hair et al., 2022). The analytical results revealed that the Cronbach's α and CR values for all latent constructs exceeded 0.90, demonstrating exceptionally high internal consistency. This provides robust evidence that the respective measurement items stably and consistently measure their corresponding underlying constructs.

4.2.2. Convergent validity verification

Convergent validity evaluates whether the observed indicators measuring the same latent construct share a high degree of common variance. In this study, convergent validity was examined using standardized factor loadings, CR, and AVE. Hair et al. (2022) established that convergent validity is successfully achieved when standardized factor loadings are ≥ 0.70 , CR is ≥ 0.70 , and the AVE is ≥ 0.50 .

The analysis showed that the standardized factor loadings for all individual measurement items ranged from 0.785 to 0.915, and all loadings were statistically significant at the $p < 0.001$ level. Furthermore, the CR values ranged from 0.907 to 0.934, and the AVE values ranged from 0.709 to 0.780, safely exceeding all recommended methodological criteria. Consequently, the measurement indicators deployed in this study were determined to possess robust convergent validity.

As demonstrated in **Table 4**, the standardized factor loadings of all observed variables exceeded 0.70, confirming that each item adequately explains its respective latent construct. Additionally, the squared multiple correlation (SMC) values for all indicators were above 0.60, indicating that a substantial portion of the variance in each measurement item is successfully accounted for by its corresponding latent variable. The CR scores for all constructs exceeded 0.90,

establishing high construct reliability, while the AVE values were consistently documented above 0.70, proving that the latent variables explain a satisfactory proportion of the variance in their observed indicators. Furthermore, Cronbach's α values for all scales were above 0.90, exhibiting excellent internal consistency. The relatively high AVE values, ranging from 0.709 to 0.780, further indicate that the observed measurement items explain a substantial proportion of the variance in their corresponding latent constructs rather than measurement error. This finding demonstrates that the indicators provide strong explanatory power and accurately represent the theoretical concepts underlying the research model, thereby reinforcing the overall quality of the measurement model.

Table 4. Results of confirmatory factor analysis, reliability, and convergent validity

Latent variable	Questions	Standardization factor loading	SMC	CR	AVE	Cronbach's α
R&D Innovation Cooperation	1	0.842	0.709	0.923	0.751	0.918
	2	0.887	0.787			
	3	0.865	0.748			
	4	0.854	0.729			
Digital Transformation Capability	1	0.901	0.812	0.934	0.780	0.931
	2	0.915	0.837			
	3	0.876	0.767			
	4	0.842	0.709			
Corporate Innovation	1	0.813	0.661	0.907	0.709	0.903
	2	0.785	0.616			
	3	0.864	0.746			
	4	0.872	0.760			

In summary, the confirmatory factor analysis verified that the measurement instruments used in this study demonstrate an acceptable measurement model fit, and both reliability and convergent validity successfully satisfied the recommended thresholds established in prior methodological literature. Therefore, the latent constructs embedded in the research model were validated as highly psychometrically sound instruments appropriate for structural equation modeling. The subsequent section details the assessment of discriminant validity utilizing the Fornell-Larcker criterion alongside the HTMT to establish the unique conceptual independence of each latent variable.

4.3. Discriminant validity verification

Discriminant validity is the procedural step of verifying whether distinct latent variables measure empirically unique and conceptually independent constructs. In other words, it tests whether the latent constructs included within the same research model are clearly distinguishable from one another, serving as a critical prerequisite for establishing the overall validity of a measurement model in structural equation modeling (Hair et al., 2022). Contemporary SEM scholarship increasingly recommends the joint application of the Fornell-Larcker criterion and the HTMT to rigorously evaluate discriminant validity (Henseler, Ringle, & Sarstedt, 2015). Accordingly, this study comprehensively examines discriminant validity by implementing both methodological approaches.

4.3.1. Discriminant validity assessment via the Fornell-Larcker criterion

Fornell and Larcker (1981) proposed that discriminant validity is successfully established when the square root of the AVE for each latent construct is greater than its correlation coefficients with any other latent constructs. This rationale

dictates that a latent construct must share more variance with its assigned indicators than it shares with other constructs in the model. In this study, discriminant validity was assessed by systematically comparing the square root of each latent construct's AVE against the inter-construct correlation coefficients.

As demonstrated in **Table 5**, the square roots of the AVE for all latent constructs were documented at 0.867, 0.883, and 0.842, respectively, all of which were found to be strictly greater than the correlation coefficients with any other latent variables. For instance, the square root of the AVE for Digital Transformation Capability was 0.883, which is substantially higher than its correlation coefficient with R&D Innovation Cooperation (0.684) and that with Corporate Innovation (0.731). Similarly, the square root of the AVE for Corporate Innovation was 0.842, comfortably exceeding its correlation coefficients with the other latent constructs, thereby satisfying the Fornell-Larcker criterion across all variables. Consequently, these findings provide empirical confirmation that the latent variables deployed in this study are conceptually distinct and independent constructs.

Table 5. Discriminant validity assessment via the Fornell-Larcker criterion

Variable	1	2	3
R&D Innovation Cooperation	0.867		
Digital Transformation Capability	0.684	0.883	
Corporate Innovation	0.639	0.731	0.842

Note: Bold values on the diagonal represent the square root of the Average Variance Extracted ($\sqrt{AVE}$), while the off-diagonal values represent the correlation coefficients between latent variables.

4.3.2. Discriminant validity assessment via the heterotrait-monotrait ratio (HTMT)

Recently, Henseler et al. (2015) pointed out that the Fornell-Larcker criterion alone may possess insufficient sensitivity to detect discriminant validity violations, and proposed the HTMT as a superior alternative. The HTMT is an advanced metric that compares the heterotrait-heteromethod correlations against the monotrait-heteromethod correlations. Generally, an HTMT value of 0.85 or below satisfies the most conservative threshold, while a value of 0.90 or below establishes acceptable discriminant validity. In this study, the calculated HTMT values among all pairs of latent constructs successfully satisfied the recommended methodological thresholds.

As demonstrated in **Table 6**, the HTMT values ranged from 0.698 to 0.811, with all figures remaining strictly below the recommended threshold of 0.85. Specifically, the highest HTMT value was documented at 0.811 between Digital Transformation Capability and Corporate Innovation; however, because it did not exceed the conservative cutoff of 0.85, discriminant validity among the latent constructs was successfully established.

Table 6. Results of the heterotrait-monotrait ratio (HTMT) analysis

Variable	1	2	3
R&D Innovation Cooperation	-		
Digital Transformation Capability	0.742	-	
Corporate Innovation	0.698	0.811	-

Furthermore, HTMT can be verified not only through point estimates but also through bootstrapped confidence intervals. In this study, a bias-corrected

bootstrapping procedure with 5,000 resamples was performed to additionally confirm the confidence intervals for the HTMT values. The bootstrap confidence interval for the HTMT index is as shown in **Table 7**.

Table 7. Bootstrapped confidence intervals for HTMT indices

Variable	HTMT	95% CI Lower	95% CI Upper	Judgment
R&D Innovation Cooperation - Digital Transformation Capability	0.742	0.653	0.808	Suitable
R&D Innovation Cooperation - Corporate Innovation	0.698	0.612	0.775	Suitable
Digital Transformation Capability -Corporate Innovation	0.811	0.729	0.878	Suitable

Henseler et al. (2015) posited that discriminant validity is successfully established if the bootstrapped HTMT confidence interval does not include the value of 1.000. The analytical results indicated that the upper bounds of the confidence intervals for all pairs of latent constructs were substantially lower than 1.000, and none of the intervals contained 1.000. Therefore, the bootstrapping verification further confirmed robust discriminant validity among the latent variables.

4.3.3. Comprehensive summary of discriminant validity verification

Synthesizing the results of both the Fornell-Larcker criterion and the HTMT analyses, R&D innovation cooperation, digital transformation capability, and corporate innovation were all verified as empirically distinct and independent latent variables. Under the Fornell-Larcker criterion, discriminant validity was supported as the square root of the AVE for every latent construct exceeded its corresponding inter-construct correlation coefficients. Concurrently, the HTMT analysis satisfied the most conservative methodological standards, with all values remaining below 0.85. Additionally, the upper bounds of the bootstrap-based HTMT confidence intervals were strictly below 1.000, providing further empirical support for discriminant validity. These consistent findings demonstrate that the measurement instruments deployed in this study accurately distinguish and measure each respective latent variable, implying that the measurement validity of the research model is fully secured. Consequently, the subsequent section details the goodness-of-fit evaluation of the structural equation model, followed by the empirical testing of the research hypotheses.

4.4. Structural model fit analysis

Following the verification of the measurement model's reliability and validity through confirmatory factor analysis, SEM was performed to evaluate the overall goodness-of-fit of the proposed conceptual framework. Structural model analysis allows for the concurrent estimation of causal relationships among multiple latent constructs, offering the distinct methodological advantage of testing direct and indirect pathways while systematically controlling for measurement error (Hair et al., 2022). In this study, AMOS 29.0 was utilized to apply the MLE method, analyzing the structural pathways connecting R&D innovation cooperation, digital transformation capability, and corporate innovation.

Identical to the measurement model evaluation, the goodness-of-fit for the structural model was comprehensively assessed using χ^2 (Chi-square), degrees of freedom (df), χ^2/df , GFI (Goodness of Fit Index), IFI (Incremental Fit Index), TLI (Tucker-Lewis Index), CFI (Comparative Fit Index), RMSEA (Root Mean Square Error of Approximation), and SRMR (Standardized Root Mean Square Residual). Generally, because the χ^2 test is highly sensitive to sample size, relying

solely on its significance probability to determine model adequacy is limited; thus, it is widely recommended to evaluate the χ^2/df ratio alongside incremental and absolute fit indices (Hair et al., 2022; Kline, 2023).

Accordingly, this study adopted the following standard thresholds for acceptable fit: $\chi^2/\text{df} \leq 3.0$; GFI, IFI, TLI, and CFI ≥ 0.90 ; and RMSEA and SRMR ≤ 0.08 . The structural model analysis yielded the following fit indices: $\chi^2 = 86.917$ ($\text{df} = 52$, $p < 0.001$), $\chi^2/\text{df} = 1.671$, GFI = 0.956, IFI = 0.977, TLI = 0.972, CFI = 0.977, RMSEA = 0.047, and SRMR = 0.037. Although the χ^2 test was statistically significant ($p < 0.001$), this is determined to be a direct consequence of the χ^2 statistic's inherent sensitivity to large sample sizes. Consequently, a comprehensive review of alternative fit indices revealed that the χ^2/df ratio was 1.671, safely satisfying the recommended threshold of 3.000 or less, while the GFI (0.956), IFI (0.977), TLI (0.972), and CFI (0.977) values all demonstrated excellent goodness-of-fit well above the 0.90 baseline. Furthermore, the absolute fit indices, RMSEA (0.047) and SRMR (0.037), also comfortably fell below the conservative standard of 0.08, providing empirical confirmation that the structural model accounts for the observed data exceptionally well. Specifically, an RMSEA value below 0.05 indicates a very low approximation error of the model, and CFI and TLI scores exceeding 0.97 imply that the proposed framework possesses robust explanatory power.

A comparison between the baseline measurement model and the final structural model showed that both configurations successfully met the recommended methodological criteria, and the structural model did not exhibit any substantial degradation in fit indices. This consistency implies that the empirical relationships among the latent variables confirmed in the measurement model remain stable within the structural pathways. In other words, the structural mechanism hypothesized in this study—R&D innovation cooperation $\rightarrow$ digital transformation capability $\rightarrow$ corporate innovation—is determined to be fully congruent with the empirical data. Additionally, to examine the variance accounted for by the proposed framework, the SMC values for the endogenous variables were analyzed. The squared multiple correlations of endogenous variables are as shown in **Table 8**.

Table 8. Squared multiple correlations (SMC) of endogenous variables

Endogenous variable	SMC (R^2)	Explanatory power
Digital Transformation Capability	0.468	46.8%
Corporate Innovation	0.654	65.4%

The analytical results indicated that the SMC (R^2) for digital transformation capability was 0.468, confirming that R&D innovation cooperation accounts for 46.8% of the variance in digital transformation capability. Furthermore, the R^2 for corporate innovation was documented at 0.654, demonstrating that R&D innovation cooperation and digital transformation capability jointly explain 65.4% of the total variance in corporate innovation. According to the criteria established by Cohen (1988), an R^2 value of 0.26 or higher is evaluated as a large effect size; thus, the proposed research model is determined to possess robust explanatory power in accounting for corporate innovation. In summary, all goodness-of-fit indices for the structural model successfully satisfied the recommended methodological thresholds, and the explanatory power (R^2) of the endogenous variables was maintained at a substantially high level. Consequently, the proposed structural framework is validated as highly adequate for explaining the empirical data and is deemed appropriate for testing the causal relationships

among the latent constructs.

4.5. Hypothesis testing

Following the verification of the structural model fit, path analysis via SEM was executed to empirically test the hypothesized causal relationships among the latent variables. Structural equation modeling provides the methodological advantage of concurrently estimating both direct and indirect pathways while analyzing causal mechanisms under a controlled state of measurement error (Hair et al., 2022). To evaluate the research hypotheses, the MLE method was applied to compute standardized path coefficients (β), standard errors (S.E.), critical ratios (C.R.), and significance probabilities (p-values). Generally, a hypothesized path was determined to be statistically significant if its C.R. value was ± 1.96 and the associated p-value was less than 0.05.

As presented in **Table 9**, all direct effect paths included in the research model were found to be statistically significant. First, R&D innovation cooperation was found to have a significant positive (+) effect on digital transformation capability ($\beta = 0.684$, C.R. = 11.247, $p < 0.001$). This implies that companies with more active R&D innovation cooperation utilize digital technologies more effectively across the organization, and more aggressively build digital-based business innovation and data-driven decision-making capabilities. Therefore, hypothesis 1 (H1) was supported. From the perspective of open innovation theory, this result aligns with Chesbrough's (2003) argument that cooperation with external innovation actors promotes the formation of new internal capabilities within a firm. Furthermore, as suggested in studies by Warner and Wäger (2019) and Verhoef et al. (2021), this can be interpreted as supporting the finding that acquiring knowledge and technology through external collaboration enhances digital transformation capabilities.

Table 9. Results of path analysis for the structural model

Hypothesis / Path	β	S.E.	C.R.	p	Result
H1. R&D Innovation Cooperation → Digital Transformation Capability	0.684	0.061	11.247	< 0.001	Adoption
H2. Digital Transformation Capability → Corporate Innovation	0.523	0.074	7.963	< 0.001	Adoption
H3. R&D Innovation Cooperation → Corporate Innovation	0.281	0.069	4.182	< 0.001	Adoption

Second, digital transformation capability was found to have a significant positive (+) effect on corporate innovation ($\beta = 0.523$, C.R. = 7.963, $p < 0.001$). This indicates that as companies effectively utilize digital technologies and successfully apply them to organizational business processes and decision-making systems, their levels of product/service innovation, organizational innovation, and process innovation improve. Therefore, hypothesis 2 (H2) was supported. From the perspective of dynamic capability theory, this empirically supports Teece's (2007) theory that firms can generate sustainable innovative performance when they reconfigure digital technologies into new organizational capabilities. It is also consistent with the positive relationship between digital transformation capability and corporate innovation presented in the studies of Vial (2019) and Verhoef et al. (2021).

Third, R&D innovation cooperation was confirmed to have a significant positive (+) effect on corporate innovation ($\beta = 0.281$, C.R. = 4.182, $p < 0.001$). This implies that more active R&D innovation cooperation with external innovation actors leads to higher corporate innovation performance. Therefore,

hypothesis 3 (H3) was supported. However, the magnitude of the direct effect ($\beta = 0.281$) can be interpreted as a pure direct effect that does not account for the indirect effect mediated through digital transformation capability; the overall impact can be more clearly identified through the mediation effect analysis presented in the next section. This result reaffirms the positive relationship between R&D innovation cooperation and corporate innovation reported in studies by Belderbos et al. (2004), Laursen and Salter (2006), and Powell et al. (1996). In particular, it suggests that even in service firms, external cooperation networks serve as a key factor promoting new service development and organizational innovation.

Meanwhile, a comparison of the standardized path coefficients revealed that the effect of R&D innovation cooperation on digital transformation capability ($\beta = 0.684$) was the largest, followed by the effect of digital transformation capability on corporate innovation ($\beta = 0.523$), and the direct effect of R&D innovation cooperation on corporate innovation ($\beta = 0.281$). These results suggest that while R&D innovation cooperation directly contributes to corporate innovation, a significant portion of this contribution likely translates into innovative performance through the process of enhancing the firm's digital transformation capability.

In summary, the structural model analysis demonstrated that H1, H2, and H3 were all statistically and significantly supported. Notably, as the structure in which R&D innovation cooperation strongly enhances digital transformation capability, which in turn promotes corporate innovation, was confirmed, the necessity to examine the mediating role of digital transformation capability has become more prominent. Consequently, the next section will employ the bootstrapping technique to verify the mediating effect of digital transformation capability and compare the direct and indirect effects to determine the presence of partial mediation.

4.6. Mediation effect analysis using bootstrapping

In this study, the bootstrapping technique was applied to verify whether digital transformation capability mediates the relationship between R&D innovation cooperation and corporate innovation. Because the traditional Sobel test has limitations in assuming a normal distribution of indirect effects, recent studies using SEM recommend verifying mediation effects through bootstrapping, a non-parametric resampling method (Preacher & Hayes, 2008; Hair et al., 2022). Bootstrapping is a method that repeatedly resamples from the original data to generate an empirical distribution of the indirect effect, thereby allowing for a more accurate evaluation of its statistical significance. In this study, 5,000 bootstrap resamples were performed using AMOS 29.0, and the mediation effect was verified using the bias-corrected 95% confidence interval. In the bootstrapping analysis, the indirect effect was determined to be statistically significant if the confidence interval did not include zero. Furthermore, by simultaneously comparing the direct and indirect effects, the presence of either partial or full mediation was identified.

As shown in **Table 10**, the direct effect of R&D innovation cooperation on corporate innovation was 0.281 ($p < 0.001$), which was statistically significant. This indicates that R&D innovation cooperation exerts a direct influence on corporate innovation. Furthermore, the indirect effect mediated through digital transformation capability was found to be 0.358 ($p < 0.001$), with the bias-corrected bootstrap 95% confidence interval ranging from 0.243 to 0.492. Since the confidence interval did not include zero, the indirect effect was determined to be statistically significant. The total effect was 0.639, confirming that the overall impact of R&D innovation cooperation on corporate innovation

is highly substantial. Notably, the finding that the indirect effect (0.358) is larger than the direct effect (0.281) implies that a significant portion of the impact of R&D innovation cooperation on corporate innovation is transmitted through digital transformation capabilities. These results suggest that digital transformation capability does not function merely as an auxiliary variable but serves as a core mechanism linking R&D innovation cooperation and corporate innovation. To further quantify the magnitude of the mediation effect, the proportion of the indirect effect relative to the total effect was calculated. The indirect effect (0.358) accounted for approximately 56.0% of the total effect (0.639), whereas the direct effect (0.281) represented the remaining 44.0%. This result indicates that more than half of the overall influence of R&D innovation cooperation on corporate innovation is transmitted through digital transformation capability, highlighting its dominant role as the principal organizational mechanism underlying innovation performance in service firms.

Table 10. Results of mediation effect analysis using bootstrapping

Path	Direct effect	Indirect effect	Total effect	Bootstrap 95% CI	p	Result
R&D Innovation Cooperation → Digital Transformation Capability → Corporate Innovation	0.281	0.358	0.639	[0.243, 0.492]	< 0.001	Significant

As shown in **Table 11**, both the direct and indirect effects were statistically significant. According to the mediation classification criteria proposed by Zhao et al. (2010), when both the direct effect of an independent variable on a dependent variable and the indirect effect through a mediator are simultaneously significant, it is interpreted as partial mediation. Therefore, this study confirmed that digital transformation capability partially mediates the relationship between R&D innovation cooperation and corporate innovation, thereby supporting hypothesis 4 (H4). More specifically, the mediation effect accounted for 56.0% of the total effect, demonstrating that digital transformation capability explains a greater proportion of the relationship between R&D innovation cooperation and corporate innovation than the remaining direct pathway. This quantitative result provides strong empirical evidence that digital transformation capability is the primary channel through which collaborative R&D activities generate innovation outcomes in service enterprises. The confirmation of partial mediation implies that R&D innovation cooperation has a dual effect: it directly contributes to corporate innovation while simultaneously promoting it indirectly by strengthening digital transformation capabilities. In other words, while collaboration with external innovation actors can inherently enhance corporate innovation, the innovative performance can be further amplified when the technology and knowledge acquired through such collaboration are effectively converted into digital-based organizational capabilities.

Table 11. Comparison of direct, indirect, and total effects

Path	Direct effect	Indirect effect	Total effect	Mediate type
R&D Innovation Cooperation → Corporate Innovation	0.281	0.358	0.639	Partial mediation

These findings empirically support the logic of the RBV, which posits that competitive advantage is generated when externally acquired strategic

resources are transformed into internal capabilities. Furthermore, it aligns with the arguments of dynamic capability theory, which suggests that the processes of resource reconfiguration and capability integration determine innovative performance. In addition, this study holds theoretical significance as it empirically validates the mechanism emphasized in open innovation theory—specifically, that the acquisition of external knowledge is linked to corporate innovation through an internal organizational capability, namely, digital transformation capability. Particularly, the finding that the magnitude of the indirect effect is larger than that of the direct effect suggests that to maximize the effects of R&D cooperation in a digital economy environment, firms should not merely focus on expanding cooperation networks. Instead, they must simultaneously strengthen their digital transformation capability to internalize the acquired knowledge and technology into digital technology, data-driven decision-making, business process innovation, and organizational culture improvement.

In summary, the bootstrapping analysis confirmed that digital transformation capability significantly mediates the relationship between R&D innovation cooperation and corporate innovation (H4 was adopted), providing empirical support for the structural mediation model proposed in this study. These results serve as crucial empirical evidence demonstrating that digital transformation capability functions as a core connecting mechanism in explaining the relationship between R&D innovation cooperation and corporate innovation.

4.7. Discussion

This study empirically examined the structural relationships among R&D innovation cooperation, digital transformation capability, and corporate innovation within service firms. The analysis revealed that R&D innovation cooperation has a significant positive (+) effect on both digital transformation capability and corporate innovation, and digital transformation capability was also confirmed to significantly enhance corporate innovation. Moreover, the bootstrapping analysis demonstrated that digital transformation capability partially mediates the relationship between R&D innovation cooperation and corporate innovation. These findings indicate that the innovative performance of service firms is not achieved solely through the expansion of external R&D cooperation; rather, it is further augmented when the technology and knowledge acquired through collaboration are effectively transformed into internal digital capabilities. That is, R&D innovation cooperation was confirmed to be a critical antecedent that directly accelerates corporate innovation while indirectly enhancing it by strengthening digital transformation capabilities. Importantly, the mediation analysis revealed that approximately 56.0% of the total effect of R&D innovation cooperation on corporate innovation was transmitted through digital transformation capability, whereas only 44.0% was attributable to the direct effect. This finding suggests that digital transformation capability is not merely a complementary organizational resource but the dominant mechanism through which externally acquired knowledge and collaborative innovation activities are translated into innovation performance. For service enterprises, this underscores that the benefits of R&D cooperation can be fully realized only when firms possess sufficient digital capabilities to absorb, integrate, and utilize externally acquired knowledge effectively.

Although the proposed structural model was theoretically supported and demonstrated satisfactory empirical fit, the cross-sectional nature of the data does not allow definitive confirmation of causal direction. It is theoretically possible that firms with higher levels of corporate innovation may also become more active in R&D innovation cooperation by attracting additional collaborative partners and innovation opportunities. However, the causal ordering adopted in this study is grounded in the resource-based view, dynamic capability theory,

and open innovation theory, all of which conceptualize external collaborative resources as antecedents of organizational capability development and innovation performance. Future research should further examine alternative causal structures, including reverse-causality and competing structural models, using longitudinal or cross-lagged research designs.

The present findings are generally consistent with previous empirical studies reporting positive relationships among collaborative R&D, digital transformation, and innovation performance. However, unlike earlier studies that primarily emphasized direct effects, the present study demonstrates that digital transformation capability serves as the principal organizational mechanism linking collaborative R&D with corporate innovation. Furthermore, by focusing specifically on service enterprises, the study extends previous empirical findings by highlighting the critical role of customer-oriented digital capabilities, platform-based innovation, and digital service transformation in enhancing innovation performance.

4.7.1. Theoretical implications

This study holds academic significance by extending existing literature in the following aspects. First, this study proposes a novel mediating mechanism to explain the relationship between R&D innovation cooperation and corporate innovation. Most prior studies have primarily focused on the direct effects of R&D cooperation on corporate innovation. However, there has been insufficient explanation regarding the specific internal organizational capabilities through which knowledge and technology acquired via external collaboration translate into innovative performance. By introducing digital transformation capability as a mediator, this study empirically clarified the structural pathway wherein R&D innovation cooperation enhances digital transformation capability, which subsequently drives corporate innovation. This offers an important contribution by providing a concrete theoretical mechanism that explains the link between R&D cooperation and innovation performance.

Second, this study expands the explanatory power of the RBV. Barney (1991) posited that a firm's sustainable competitive advantage stems from possessing resources that are valuable, rare, inimitable, and non-substitutable (VRIN). However, recent research emphasizes that merely acquiring resources is insufficient to sustain a competitive advantage; rather, the process of transforming these resources into internal organizational capabilities is crucial. The findings of this study demonstrate that corporate innovation is further enhanced when external knowledge and technology acquired through R&D innovation cooperation are converted into the organizational capability of digital transformation capability. This empirically validates the importance of strategic resource utilization and capability-building processes within the RBV framework.

Third, this study provides empirical support for dynamic capability theory. Teece (2007) explained that in a rapidly changing business environment, firms can sustain a competitive advantage only when they possess the capabilities to sense the external environment, seize new opportunities, and continuously transform (reconfigure) organizational resources. The finding that digital transformation capability mediates the relationship between R&D innovation cooperation and corporate innovation empirically demonstrates that the internal reconfiguration of externally acquired innovative resources is a core mechanism determining innovative performance.

Fourth, this study extends open innovation theory. Although Chesbrough (2003) emphasized that leveraging external innovative resources is a pivotal strategy for corporate innovation, empirical explanations regarding the specific internal organizational capabilities that link external cooperation to innovation

performance remain limited. By presenting digital transformation capability as a mediator, this study confirmed that the effects of open innovation are amplified through digital transformation capabilities. This offers substantial academic significance by suggesting a new theoretical perspective that integrates open innovation theory with digital transformation research.

Lastly, this study presents a more sophisticated causal relationship than previous research by simultaneously verifying direct and indirect effects within the service industry using SEM and bootstrapping. In particular, by confirming the partial mediating effect of digital transformation capability, this study extends existing research on service firm innovation and proposes a novel research model for future digital-based innovation studies.

Beyond extending general innovation theories, this study offers a theoretical contribution that is unique to the service industry. Unlike manufacturing firms, service enterprises create value primarily through customer interaction, digital service delivery, platform ecosystems, and customer experience innovation. The findings demonstrate that digital transformation capability functions not only as an organizational capability but also as a service-specific capability that enables firms to transform collaborative R&D outcomes into customer-centered digital value creation. This service-oriented innovation mechanism extends existing innovation theory by explaining how digital transformation facilitates platform innovation, customer experience enhancement, and digital service innovation within knowledge-intensive service environments.

From the perspective of human resource management (HRM), this study also contributes by highlighting that digital transformation capability is fundamentally supported by employees' digital competencies, organizational learning, cross-functional collaboration, and continuous capability development. The findings suggest that service firms cannot fully realize the innovation benefits of R&D cooperation through technological investment alone; rather, sustained investments in employee digital skills, knowledge sharing, leadership for digital transformation, and human capital development are essential for transforming external knowledge into innovation outcomes. Therefore, this study extends HRM research by demonstrating that human resource development constitutes a critical organizational foundation for successful digital transformation and corporate innovation.

4.7.2. Managerial implications

The findings of this study offer various practical implications for establishing innovation strategies in service firms and designing government innovation support policies. First, managers of service firms should perceive R&D innovation cooperation not merely as joint R&D activities, but utilize it as a strategic tool to accelerate digital transformation. The impact on corporate innovation can be maximized when firms establish systems to actively utilize the technologies and information acquired through collaboration with external research institutes, universities, customers, and suppliers within the organization.

Second, continuous investment in digital transformation capability is essential. In this study, the indirect effect through digital transformation capability was found to be larger than the direct effect of R&D innovation cooperation. This implies that the process of connecting the knowledge and technology acquired through collaboration to digital-based business innovation internally is more crucial than the cooperation itself. Therefore, firms must continuously invest not only in building digital infrastructure but also in data-driven decision-making systems, artificial intelligence utilization, cloud-based collaboration platforms, and fostering a digital organizational culture.

Third, the innovation strategy of service firms needs to shift from a

technology-centered approach to a capability-centered approach. Recently, in the service industry, service innovation and customer experience innovation have become more vital than product innovation. Consequently, a strategy is required to integrate digital technologies beyond mere adoption into the overall business processes and methods of customer value creation. The results of this study empirically demonstrate that digital transformation capability is a core competitive factor for innovation in service firms.

Fourth, government innovation support policies should expand from focusing primarily on R&D support to concurrently incorporating policies that strengthen digital transformation capabilities. Currently, many government support programs focus heavily on joint R&D or technology development support, whereas programs aimed at enhancing digital capabilities to effectively utilize R&D outcomes internally remain relatively scarce. Therefore, the government needs to pursue integrated innovation policies that link R&D support with digital talent nurturing, data utilization training, AI-based innovation consulting, and support for building digital platforms.

Lastly, service firms need to establish digital innovation governance to sustainably manage the performance of R&D innovation cooperation. When technologies and information obtained through external collaboration are linked with internal digital platforms, and an organizational culture that promotes continuous learning and sharing is established, the effects of R&D cooperation can translate into long-term innovative performance.

Managerial priorities should also differ according to firm characteristics. For small and medium-sized service enterprises (SMEs), limited financial and technological resources make it particularly important to utilize government-supported collaborative R&D programs, cloud-based digital platforms, and external digital expertise to strengthen digital transformation capability. In contrast, large service enterprises should focus on establishing integrated digital innovation ecosystems, expanding AI-driven data analytics, and coordinating digital transformation across multiple business units. In addition, managerial strategies should vary across service sub-industries. Platform-based service firms should prioritize digital ecosystem expansion, platform governance, and data-driven customer value creation, whereas traditional service enterprises should focus on digitalizing service delivery processes, improving customer experience, and gradually integrating digital technologies into existing business operations.

5. Summary, conclusion and limitations

5.1. Summary of findings

The purpose of this study was to empirically examine the structural relationships among R&D innovation cooperation, digital transformation capability, and corporate innovation in service firms, with a particular focus on verifying the mediating effect of digital transformation capability. While prior research has predominantly focused on the direct impact of R&D innovation cooperation on corporate innovation, this study introduced digital transformation capability as a mediator to systematically explain the internal mechanism linking R&D innovation cooperation to corporate innovation. To achieve this, a survey was conducted among domestic service firms for one month in April 2026, and a total of 328 questionnaires were collected. Following a data cleaning process, a final sample of 305 questionnaires was utilized for the empirical analysis. Using SPSS 29.0 and AMOS 29.0, data analysis involved descriptive statistics, CFA, SEM, and bootstrapping-based mediation analysis.

The empirical findings are summarized as follows: First, the CFA results indicated an excellent model fit for the measurement model. The

Cronbach's α , CR, and AVE for all latent variables met the recommended thresholds, thereby establishing the reliability and convergent validity of the measurement scales. In addition, discriminant validity was sufficiently established through the Fornell-Larcker criterion and HTMT ratio analysis, confirming the structural validity of the research model. Second, the structural model analysis revealed that all hypothesized direct effects were statistically significant. R&D innovation cooperation exerted a significant positive (+) effect on digital transformation capability, which in turn significantly enhanced corporate innovation. Furthermore, R&D innovation cooperation was found to have a direct positive (+) effect on corporate innovation. Third, the mediation analysis using bootstrapping demonstrated that digital transformation capability significantly mediated the relationship between R&D innovation cooperation and corporate innovation. Notably, because both the direct and indirect effects were significant, a partial mediation effect was confirmed, with the magnitude of the indirect effect exceeding that of the direct effect. This implies that a substantial portion of the impact of R&D innovation cooperation on corporate innovation is transmitted through digital transformation capabilities.

In conclusion, R&D innovation cooperation in service firms not only directly enhances corporate innovation but also further accelerates it by strengthening digital transformation capabilities. Therefore, digital transformation capability can be interpreted as a core strategic capability that explains the innovative performance of service firms.

5.2. Conclusion

This study holds significant academic value by proposing a novel structural mechanism that accounts for the innovative performance of service firms. Specifically, unlike prior literature that has focused primarily on the direct relationship between R&D innovation cooperation and corporate innovation, this study introduced digital transformation capability as a mediator to empirically clarify the specific pathways through which technologies and knowledge acquired via external collaboration translate into corporate innovation.

The findings demonstrate that R&D innovation cooperation does not merely end with securing external innovative resources; rather, corporate innovation is further accelerated when these resources are effectively converted into internal digital transformation capabilities. This result comprehensively supports the RBV, dynamic capability theory, and open innovation theory, empirically confirming that digital transformation is a pivotal organizational capability determining the innovative performance of service firms.

Furthermore, this study validated that digital transformation capability partially mediates the relationship between R&D innovation cooperation and corporate innovation. This indicates that to maximize the effects of external collaboration, firms must look beyond expanding collaboration networks and implement strategies to internalize the acquired technologies and information into internal capabilities by aligning them with digital technologies, data-driven decision-making, and a digital organizational culture.

Managerially, the findings provide differentiated implications for both service firms and policymakers. For service enterprises, strategic priorities should be aligned with firm characteristics and business models. While SMEs should focus on strengthening digital capabilities through collaborative R&D networks and external digital support, large service firms should emphasize organization-wide digital integration, AI-based innovation management, and platform ecosystem development. Likewise, platform-based service firms should prioritize digital ecosystem expansion and customer data utilization, whereas traditional service firms should concentrate on digitally transforming service processes and

enhancing customer experience. From a policy perspective, short-term policy initiatives should prioritize collaborative R&D subsidies, digital technology adoption programs, AI consulting services, and cloud infrastructure support to accelerate firms' digital transformation. In contrast, long-term policy strategies should focus on cultivating digital talent, strengthening university–industry collaboration, expanding digital education programs, and developing sustainable digital innovation ecosystems that enhance the long-term competitiveness of the service industry.

5.3. Limitations

Despite its contributions, this study is subject to several limitations. First, because this study relied on a cross-sectional survey of domestic service firms, caution should be exercised when making causal interpretations or generalizing the findings to other industries or countries. Although the proposed causal ordering is theoretically grounded in the resource-based view, dynamic capability theory, and open innovation theory, reverse causal relationships cannot be completely ruled out. For example, firms with higher levels of corporate innovation may also be more likely to engage actively in R&D innovation cooperation. Future studies should employ longitudinal, cross-lagged, or competing structural model analyses to further validate the causal direction of the proposed relationships.

Second, although this study implemented several procedural remedies to reduce common method bias—including anonymous participation, voluntary responses, and randomized questionnaire item ordering—and additionally conducted Harman's single-factor test, which indicated that common method bias was not a serious concern, the use of cross-sectional self-reported survey data may still involve some degree of residual common method variance. Therefore, future research is encouraged to employ longitudinal research designs, multi-source data, or objective performance indicators to further minimize potential method bias and strengthen causal inference.

Third, this study focused exclusively on service firms operating in South Korea. Because the institutional environment, digital policy framework, and innovation ecosystem in South Korea differ from those of other countries, the empirical findings may not be directly generalizable to different national or industrial contexts. Accordingly, the conclusions of this study should be interpreted primarily within the Korean service industry context. Future comparative studies involving multiple countries and industries would help verify the broader applicability of the proposed research model.

Fourth, digital transformation capability was conceptualized and analyzed as a higher-order integrated construct. Although this approach is theoretically appropriate for examining the overall mediation mechanism, it may obscure the heterogeneous effects of individual digital capability dimensions. Consequently, the empirical findings should be interpreted as reflecting the overall organizational impact of digital transformation capability rather than the relative importance of specific sub-dimensions, such as digital infrastructure, data analytics capability, or digital organizational culture. Future studies should investigate these dimensions separately to provide a more detailed understanding of their distinct mediating roles.

5.4. Future research directions

Building upon the limitations of the present study, future research may be systematically organized into four complementary research streams. First, future studies should focus on data design optimization. Since the present study employed a cross-sectional survey based on self-reported responses, future research should adopt longitudinal, panel, or cross-lagged research

designs to strengthen causal inference. The incorporation of multi-source data, objective performance indicators, and archival datasets would further improve the robustness and reliability of empirical findings.

Second, future research should expand the underlying research model and explanatory mechanisms. In addition to examining the overall mediating role of digital transformation capability, future studies could investigate multiple mediation models, moderated mediation mechanisms, and the heterogeneous mediating effects of individual digital capability dimensions. Such approaches would provide a more comprehensive understanding of how collaborative R&D influences innovation performance under different organizational conditions.

Third, future studies should broaden the contextual boundaries of the proposed research model. Since this study focused on South Korean service enterprises, comparative analyses across different countries, industries, and institutional environments would enhance the generalizability of the findings. Cross-country comparisons would also provide valuable insights into how national digital policies and innovation ecosystems influence collaborative innovation and digital transformation.

Finally, future research should incorporate emerging digital technologies into innovation research. As artificial intelligence, big data analytics, cloud computing, platform ecosystems, and generative AI continue to reshape service innovation, future studies should examine how these emerging technologies interact with R&D innovation cooperation and digital transformation capability to generate new forms of corporate innovation. Such investigations would further extend the theoretical and practical implications of digital transformation research.

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Informed consent statement: Informed consent was obtained from all participants prior to their participation in the survey. Participation was voluntary, and respondents were informed of the purpose of the study, the anonymous and confidential treatment of their responses, and the academic use of the collected data.

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