Digital Innovation: Organizational Foundation and Chinese Heterogeneity

Qu Yongyi*
Institute of Industrial Economics (IIE), Chinese Academy of Social Sciences (CASS), Beijing, China

Abstract: *The advancement of digital innovation requires a distinctive organizational structure, different from those for non-digital innovation. The research literature, however, has confused appropriate forms of organization for digital innovation with those for non-digital innovation. Organizational heterogeneity, which is often overlooked in research on digital innovation, determines a country's core digital competencies. From a holistic perspective of corporate organization, industrial organization and innovation system, this study has identified the unique organizational structure for digital innovation in China by comparing organizational structures for digital and non-digital innovations. In terms of corporate organization, Chinese companies have intensified internal competition and cooperation to incentivize digital innovation in areas with mid- and short-term goals of profitability. In terms of industrial organization, multi-platform enterprises and diverse use cases may enhance economies of range and multi-path exploration of digital innovation. In terms of innovation system, administrative intervention in specific domains of the digital economy may help to shape expectations of innovation entities and coordinate their behaviors.*

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1. Introduction

Digital innovation, characterized by digitalization, Artificial Intelligence (AI) and the Internet of Things (IoT), is the most important technological driver of future social and economic development worldwide. As governments have recognized, the digital revolution will remake the technological, industrial and economic landscapes of the world. As such, digital innovation has aroused great academic interest, not only due to its significance, but also because some of its manifestations cannot be adequately explained by traditional economic theories. Some scholars contend that digital technology has shifted the focus of economics research, even though it does not challenge fundamental economic theories (Goldfarb and Tucker, 2019). Others believe that internet-based technology is transforming the nature of industries and challenging traditional economic theories (Jiang, 2017), causing the entire field of economics to be rewritten in the wake of the digital innovation wave (Li, 2017). In other words, digital innovation creates not only opportunities for economic development, but also new horizons for economic theories. According to the logic of economic theories, economics for digital innovation must identify unique phenomena of digital innovation that cannot be adequately explained by traditional economics and existing economic theories must be expanded and, in some cases, revised to provide

* CONTACT: Qu Yongyi, email: qyy@cass.org.cn.

coherent and straightforward explanations for digital innovation that differ from the traditional techno-economic paradigms.

Current research on digital innovation is following three interdependent paths:

The first path is identification of the technological and economic uniqueness of digital innovation as opposed to traditional innovation, such as the lower costs of search, circulation, tracking and verification (Goldfarb and Tucker, 2019). Information products are characterized by the non-competitiveness of consumption, the near-zero marginal cost of information, the virtualization of the digital market and big data as a key input (Zhang, 2022). Digital innovation features multitiered and complex technology and product architectures (Bogers et al., 2022) and generativity that is distinct from those of traditional technologies (Zittrain, 2006).

The second path is research on the uniqueness of corporate competition and management practices that are compatible with the techno-economic characteristics of digital technology. For example, digital technology has reshaped corporate pricing and product behaviors, as shown by the emergence of new strategic competitive behaviors such as self-preferencing, refusal to deal, differentiated pricing, aggressive subsidy and killer acquisition (Zhang, 2022). Digitalization has elevated user value orientation and substitutive competition to the forefront of enterprise management, enabling targeted marketing, modularized and flexible manufacturing, iterative product design, open-source R&D and a pluralistic and elastic workforce (Qi and Xiao, 2020). Digital innovation is an open, multi-use-case, continuously iterative, dynamic and interactive process and because digital knowledge is distributed across an ocean of entities to be recombined by digital innovators, digital innovation is characterized by both distributed and recombinant innovations (Liu et al., 2020).

The third path is research into the evolving organizational structure compatible with the traits of digital technology. Digital innovation often relies on industrial ecosystem interactions and open innovations through industrial platforms, unlike the internal product platforms of traditional R&D institutions (Gawer, 2009). According to the mirroring hypothesis in the traditional organizational research, technological modularization and standardization are expected to facilitate the modularization of organizational relationships within and among enterprises. Due to the complex architecture resulting from the fusion among digital and other technologies, digital technology has not only facilitated the modularization of technological architecture, it has also increased the division of labor and enhanced knowledge interactions within and across organizations (Lee and Berente, 2012).

The research literature on digital innovation has focused on how institutional and organizational factors influence a nation's capacity for digital innovation. In the research literature, the economic paradigm of digital innovation is derived from the technological paradigm of digital innovation. As a result, the institutional and organizational traits of digital technology underscored in the research literature are those of traditional non-digital technology innovation. In other words, the institutional and organizational patterns of digital innovation found in the research literature are the general norms or essential conditions needed for a country to become a digital power. However, the history of industrial development demonstrates that countries can become technological leaders based on different institutional and organizational structures (Hall and Soskice, 2001) and the determinant of a country's core technological competencies arises from institutional and organizational factors that are distinct from those of other nations, which include, the government, enterprises and non-business organizations (Mowery and Nelson, 1999).

The research literature on digital innovation may have ignored an essential question regarding the nature of organizational uniqueness underlying a country's core competencies for digital innovation. If academia cannot provide a logically coherent analytical framework and key variables for this question, it cannot comprehend how China became a digital powerhouse. In an interwoven process of disruptive innovation, technological and industrial revolutions take place in coordination with corporate organization, industrial organization and innovation system. While internal corporate structures and processes are the cornerstone of corporate organization, industrial organization is primarily concerned with the impacts of market competition on the corporate and industrial performance of specific industries (Carlton and Perloff, 2005), whereas, the innovation system deals with how interactions among non-corporate and non-market entities may influence the performance of industrial innovation (Soete et al., 2010). Corporate organization, industrial organization and innovation system influence digital innovation at the corporate, industrial and sectoral levels. China's new industrial revolution, spearheaded by digitalization, AI and IoT, is an exploration of an economic paradigm built on the current one. It should be based in its fundamental systems and compatible with the goals and technological paths of digital innovation — a paradigm that outcompetes that of other nations via digital innovation. Under this paradigm, China's digital innovation competencies are driven by the unique traits of its corporate organization, industrial organization and innovation system.

The purpose of this research is to investigate China's organizational uniqueness in digital innovation in comparison to other nations. After reviewing corporate, industrial and sectoral innovation theories, this research compares organizational practices for digital innovation in China and the United States, develop a holistic perspective of corporate organization, industrial organization and the innovation system and compare the organizational attributes of digital innovation with those of non-digital innovation. Section 2 discusses the corporate organization of digital innovation in China from the perspective of internal corporate organizational structure and processes. Section 3 examines the industrial organization of digital innovation in China in terms of corporate boundaries and market competition. Section 4 identifies China's digital innovation system based on non-market interactions among corporate and non-corporate innovation entities. Section 5 offers policy suggestions. Despite their best efforts to generalize in the theoretical analysis, all of these factual discussions will center on China and the United States, which are widely regarded as digital powerhouses.

2. Corporate Organizational Foundation for Digital Innovation

2.1 Mechanisms for Corporate Organization Spurring Digital Innovation

Enterprises exist as organizations in which employees work together to achieve common goals in a cost-effective manner. These employees act in their self-interest and have a degree of autonomy in how to attain their targets. Once aligned with the goals of digital innovation, particularly the need to integrate knowledge and resources and incentivize participants in specific use cases, the organizational forms of enterprises , including structure, processes, automation, incentives and other factors - optimally enhance the efficiency and effectiveness of the digital innovation.

Organizational structure influences digital innovation by means of three mechanisms: First, the organizational structure and business processes affect the capacity to identify and integrate heterogeneous resources and thus their digital innovation. Integration of diverse knowledge is necessary for all types of innovation. However, digital innovation entails a much higher level of heterogeneity of knowledge resources (Barrett et al., 2012) due to the pervasiveness of digital technology, the diversity of complementary knowledge and the more significant traits of integrated and distributed innovations. Demand for heterogeneous resources is reflected on both the input (grouping of innovation assignments) and output (recombination of innovation results) sides, thereby transforming the information dependencies among innovation projects. Since all new organizational forms result from the serial or parallel combination of existing organizational forms, the ever-changing resource demand and information dependencies necessitate a faster recombination of organizational forms. In this context, organizational restructuring will enable businesses to respond more effectively to dynamic shifts in the heterogeneity and integration level of knowledge resources for digital innovation. Some businesses, for instance, have replaced innovation teams with "task-expertise-person" units, which feature a more dynamic structure and division of labor (Brandon and Hollingshead, 2004). When specific requirements for knowledge resources arise as a result of the most recent emergence of digital innovation opportunities, businesses are able to swiftly replace and combine these units.

Second, internal corporate coordination influences the trust and cooperation of employees participating in digital innovation, thereby affecting their ability to innovate. The uncertainty of digital innovation and the heterogeneous resource requirements mean that firms have to bring together more numerous and diverse participants (Bereznoy et al., 2021), which makes organizational coordination even more challenging. Furthermore, the potential asymmetry of information and knowledge possessed by employees participating in digital innovation has led to a trust crisis among them, which has to be addressed with even more organizational coordination. Hence, the transition of hierarchical and control-oriented to flatter and actor-oriented coordination is conducive to smoothening the ever-changing and frequent coordination among innovators (Fieldstad et al., 2012). For instance, an increasing number of digital start-ups rely on self-organization as the primary coordination mechanism and set up platforms for self-organized innovation. Employees use collaborative tools to share information via standard interfaces and communication channels with technical support, and remind collaborators to keep track of updates to an innovation task in progress. Innovators find it more convenient to communicate directly with each other than to rely on procedural planning and integration to mitigate information asymmetry and increase the depth, scope and agility of collaboration for digital innovation.

Third, corporate incentives influence employees' opportunistic tendencies for digital innovation, thereby impacting the outcomes of digital innovation through emergent and accidental behaviors. Under traditional bureaucratic hierarchies and stringent performance evaluations, employees are expected to achieve clearly defined organizational goals for innovation. However, both the process and outcomes of digital innovation are uncertain (Troise et al., 2022). On the one hand, senior management's inability to monitor every participant in innovation gives rise to opportunistic conduct. On the other hand, digital innovation is frequently the result of "limited accidental discoveries", and unplanned interactions among employees may result in highly valuable innovations (Austin et al., 2012). In this situation, there is a greater degree of contract imperfection among enterprises and employees, which means that contractual incentives alone are not enough to motivate employees to innovate. External incentives based on hierarchies and performance metrics are giving way to employee self-motivation (Ryan and Deci, 2017), aiding businesses in reducing opportunistic behavior and resolving the dilemma of high-level monitoring. Many large organizations, for instance, have chosen to abandon the hierarchical system and provide employees with control and decision-making authority, thereby encouraging them to make fortuitous discoveries.

2.2 Heterogeneity of Corporate Organizations for Digital Innovation

Corporate organizations that are better at digital innovation share common traits. They are heterogeneous in terms of structural reconfigurability, agile in development and highly decentralized in coordination and incentives. The combination of these traits stimulates digital innovation; however, no single trait can exert significant influence without the assistance of the others. In other words, an effective organization is one with a coherent design.

All innovative enterprises must deal with the issue of increasing organizational complexity. To allow digital innovation to occur, enterprises must adapt their organizational structure to the technological and architectural characteristics of enterprises that are better at digital innovation. This cannot be accomplished just by modularizing the organizational structure. The increasing complexity involved in digital innovation can be dealt with by adopting a reconfigurable structure rather than simply reduced by trimming organizational hierarchies and modules, as is the case with traditional innovations. The traditional organizational structure is designed to reduce organizational complexity so that various functions can be integrated while maintaining simplicity. The distinction among the two is the infinite recombination potential of digital technology (Arthur, 2009). Digital innovation is distinguished from other types of innovation by a higher level of knowledge integration and architectural complexity; therefore, a reduction in structural complexity is likely to reduce the diversity of knowledge within organizations, thereby affecting the possibility and novelty of digital innovation. In addition to the management of complexity, there is also a need to maintain the diversity of knowledge and the flexibility of digital innovations. To strike this balance, digital innovators have divided their organizations into numerous reconfigurable units that are reallocated from time to time when opportunities for innovation arise, rather than specializing in specific domains or functions (Galbraith, 2010). This enables large enterprises to overcome organizational inertia and complexity and coordinate their activities to capitalize on opportunities for digital innovation. For instance, IBM has implemented a reconfigurable organizational structure that comprises stable and variable sections to offer integrated and tailored solutions. The stable section encompasses fundamental business processes, such as finance and customer relations, which are shared services. On the other hand, the variable section includes reconfigurable innovation teams and decision-makers who are responsible for allocating resources and setting priorities. The companywide teams pursue innovation opportunities and move from one project to another. The stable business processes have minimized the cost of reconfiguration. IBM has evolved into one of the world's most complex organizations. It has become a super-matrix organization that encompasses regional, sectoral, customer and product dimensions. Thanks to the reconfigurable structure, IBM's activity modules (innovation teams) can be efficiently adjusted and coupled to take advantage of emerging innovation opportunities.

Innovators design their organizational processes to expedite innovation. In the case of digital innovation, however, companies must closely follow changing user preferences and technological dynamics, as well as changing innovation targets and needs. As a result, an agile process of trial-and-error, feedback and iteration is required (Barton et al., 2018). Traditional organizational processes are designed to minimize such interferences even though it is difficult to eliminate change and iteration of goals. The "linear cascade process" is a traditional method of digital innovation where each stage of innovation is reliant on the output of the one before it. This method was widely used in software development in the past. Nowadays, the speed of innovation increasingly matters due to the short lifespans of digital technologies and products. Companies that place a high priority on digital innovation began to ditch the linear cascade process. They have adopted the new strategy of "swift start and frequent iterations" instead of the old approach of "optimizing processes to reduce iteration". To illustrate, consider digital start-ups. Despite their proficiency in identifying innovation opportunities, startups are unable to follow future customer requirements or lack the resources to develop complete solutions. After the first step of "defining product concept" in the linear cascade process, they proceed with an agile process of trial and error, feedback and iteration to create a minimally viable product with essential features for a few initial users before continuously improving their products based on user feedbacks. This "lean entrepreneurship" strategy is most prevalent in digital entrepreneurship (Ries, 2011). Rapid adoption of agile processes has supercharged digital innovation (Guinan et al., 2019). Large organizations that previously emphasized standard processes have embraced agile and iterative innovation project processes in order to complete tasks with uncertain objectives and outcomes. Some firms have become more tolerant toward failure (Haffke et al., 2017), thereby securing the correct path to innovation via trial and error. Inspired by integrated digital innovation, traditional businesses are attempting to surmount a culture that resists teamwork and iteration and adopt agile processes to shorten the development cycle.

Some innovative businesses favor decentralization as a means to boost employee self-motivation and innovation participation. In the realm of digital innovation, however, companies have taken decentralized coordination one step further to encourage their workforce to identify and capitalize on accidental discoveries, inventing a holacracy in which authority is distributed among self-organizing groups without hierarchies (Robertson, 2015). In traditional hierarchical organizations, middle- and upperlevel management use their authority to incentivize employees to perform their duties and coordinate their behavior. In order to adapt to the changing environment, traditional enterprises have implemented horizontal coordination mechanisms such as cross-functional teams based on formal relationships and social networks based on informal relationships, in addition to the hierarchical structure and coordination through external incentives. However, non-hierarchical organizational coordination functions as a supplement to hierarchical coordination rather than a replacement for it. As previously mentioned, the unpredictability of digital technology has made internal governance more difficult and fostered opportunistic behavior. Faced with digital innovation opportunities, employees need entrepreneurial self-motivation and business units need trust and coordination through autonomous communication in order to collaborate to pursue opportunities, thereby avoiding inefficiencies and other negative effects of a hierarchical system. As a result, an increasing number of digital innovation-focused businesses have adopted organizational coordination in which self-organized groups play a leadership rather than a supporting role. Self-organization comes in a variety of forms. Some of them exist within innovation teams, while others have revolutionized entire firms. As the first coordination mechanism that completely and mandatorily enforces self-organization throughout entire organizations (Lee and Edmondson, 2017), holacracy has drawn considerable public interest. In a holacracy, positions are replaced by roles and teams are grouped into circles, eschewing a stable organizational structure. In various circles, employees assume different roles and determine the trajectory of their work accordingly. By holding governance meetings, the circles "continually bring the focus back to the roles" and set up ways for internal roles to work together. In the meantime, one circle coordinates with other circles regarding their activities and resource distribution through dynamic tactical meetings (Schell and Bischof, 2022). Since the US e-commerce platform Zappos implemented a holacracy, this radical coordination mechanism has spread to numerous Silicon Valley start-ups and well-established corporate titans (Ackerman et al., 2021).

2.3 Chinese Companies for Digital Innovation: Organizational Strengths and Challenges

Countries have different institutions, markets and cultures. The organizational structures of businesses in many nations share common patterns and exhibit distinct trends. Unlike other countries, the organizational structure of Chinese businesses is profoundly influenced by the vast and diverse local market demand as well as the traditional hierarchical culture. Due to the institutional design of internal competition and cooperation, Chinese companies have intensified internal competition and cooperation to incentivize digital innovation in areas with mid- and short-term goals of profitability. However, in the long-term exploratory domains of digital innovation, the hierarchical organizational structure of Chinese businesses presents a challenging constraint.

Supported by the ultra-large and diversified local market demand, Chinese companies have intensified internal competition and cooperation processes, which facilitate the simultaneous development of commercial digital innovation products with differentiated technological paths. For many digital innovation companies, the size of their limited domestic market and convergent market demand call for a balance in their explorations of diverse opportunities; such explorations, if too scattered, could divert innovation away from market demand. In the developed world, companies encourage the parallel development of competitive technologies by multiple business units (Song et al., 2016). However, such internal competition must be superseded by internal cooperation after the commercialization stage, in which only one product or technology is marketed to avoid internal conflict of interest and waste of resources. However, things are different for digital innovation firms in China, thanks to the country's huge and varied domestic market. China's information authorities and consumers are tolerant of digital innovation, encouraging Chinese businesses to experiment with more radical internal competition and cooperation. In addition to encouraging the development of competitive technologies internally, they simultaneously introduce competitive products to the market for testing and iteration. Tencent was one of the first businesses to institutionalize such internal competition and cooperation (Murmann and Zhu, 2021). In 2010, Tencent established three teams from two departments to simultaneously develop three competitive instant messaging products in three cities, including Mobile QQ, QQ Address Book and WeChat. Once completed, these products were released simultaneously. This arrangement led to intense competition among teams for internal resources and external complementary resources from telecom operators. They could only achieve success by accelerating organizational learning and product iteration. Tencent provided all teams with access to its infrastructure, essential technologies and platforms for knowledge sharing. It coordinated the technological cooperation of multiple teams. For instance, it permitted WeChat to imitate the functionality of other products and requested assistance from other teams in promoting WeChat. Intense cross-departmental competition and cooperation allowed WeChat to introduce new features and, for the first time, transform an instant messaging application into a multi-functional, open ecosystem, which represents a world-class digital innovation originating in China.

Under the influence of a hierarchical culture and planned organizational norms, however, the majority of Chinese companies have struggled to reduce organizational hierarchies and decentralize the organization, impeding the continuous exploration and active response of their employees to capitalize on the long-term opportunities presented by digital innovation. As previously discussed, organizational development trends for digital innovation companies include collaboration and decentralized incentives. Under this trend, Chinese companies are also seeking to establish flat and decentralized network coordination mechanisms. For instance, Red Collar Group is one of the first apparel companies to develop and effectively implement a customization platform. By eliminating intermediate management positions, it has transformed from a highly hierarchical to a flat organization, allowing employees to respond directly to customer needs while the management focuses on service and supporting activities (Qi and Xiao, 2020). Traditional Chinese culture, which places a premium on order and stability and the legacy of the planned economic system present Chinese companies with greater institutional and conceptual barriers when it comes to reducing hierarchies and embracing decentralization than American companies. These obstacles hinder their organizations' adoption and transition of digital innovation. The challenges are particularly severe for state-owned businesses (SOEs). When presented with digital innovation opportunities, SOEs are advantageously positioned to access data and assert their institutional legitimacy. However, due to the limitations imposed by their multilevel, vertical and enclosed organizational structure, their capabilities have been underutilized. Numerous SOEs have established relatively flat organizational structures for digital innovation, modeled after "digital laboratories", to mitigate the effects of hierarchies (Haffke et al., 2017). For example, China Mobile has established the China Mobile Research Institute. This two-pronged strategy increases the efficacy of digital innovation. The downside is that the ensuing organizational isolation may inhibit collaboration among the highly hierarchical and flat portions of the organization.

3. Industrial Organizational Foundation for Digital Innovation

3.1 Industrial Organization as a Driving Force of Digital Innovation

Industrial organization is a branch of economics that examines corporate boundaries and intra-industry market structure, as well as inter-firm competition and cooperation. The vertical and horizontal integration of firms both results from and determines their technological capabilities (Chandler, 2006). Such relationships of competition and cooperation are determined by market position, product differentiation, consumer demand and other corporate factors that affect the intensity of the technological innovation incentives. For the same industry, some countries derive their competitiveness from large companies, while other countries rely on specific industrial groups, due to factors at the level of industrial organization, particularly aggregate factors that cannot be decomposed into individual businesses (Huang and He, 2015). Exogenous technological paradigm shifts are likely to reshape corporate boundaries, intra-industry market structures and the relationships of competition and cooperation among enterprises in the digital economy, thereby influencing the behaviors and performance of corporate digital innovation.

Industrial organization influences digital innovation through two distinct mechanisms:

First, interactions among companies promote digital innovation by facilitating the exchange, assimilation and incorporation of demand information and technological and industry-specific knowledge, which are essential for digital innovation. Knowledge of market demand comprises knowledge of individualistic and diverse consumer demand, as well as knowledge of the need for digital transition in particular industries. Industry-specific production knowledge includes knowledge of production processes and product details. Digital innovation arises from the development and deployment of digital technologies such as 5G, big data and AI in diverse industrial sectors (Di Vaio et al., 2021). In traditional non-digital innovation, the relationship among upstream and downstream enterprises is centered around the transaction of intermediate inputs under the "architecture-module" technological paradigm for integrated innovation. This relationship promotes innovation by assuring the stable supply of and dedicated investment in innovation factors via strategic behaviors such as multi-source supply, long-term contracts and exclusive transactions (Tirole, 1998). In contrast to the integration of architectures and modularized products in non-digital domains, digital innovation brings together the proprietary knowledge of various industries and sectors, such as process know-how, demand information and technological characteristics, to develop systematic innovation solutions (Hinings et al., 2018). In other words, industrial organization facilitates digital innovation not only through the supply of intermediate and modularized products, but also through the flow and integration of knowledge among firms within and across industries. In smart manufacturing, for example, digital innovation requires specialized knowledge such as communication standards and protocols, in addition to diverse knowledge about manufacturing processes, material formulation, software development, sensors, data collection and digital modeling. Only by integrating knowledge from various disciplines within an industrial organization can smart manufacturing innovations become more productive.

Second, digital innovation is turbocharged by new forms of competition, cooperation and industrial organization. Innovation, whether digital or non-digital, depends on a delicate equilibrium among two forces. On the one hand, innovators should receive monopolistic return as an incentive to innovate. On the other hand, competition is necessary to prevent monopoly from impeding continuous innovation (Aghion and Tirole, 1994). Complexity and uncertainty often discourage digital innovation. Therefore, an effective industrial organization must be one that fully exploits digital innovation's intrinsic incentives. First, industrial organization should balance business competition with cooperation to increase return from digital innovation. In the era of digital innovation, the most important forms of organizational competition are competition among technology paths, standards and platforms, as opposed to traditional innovation centered around competition among businesses and products (Wiegmann et al., 2022). While maintaining sufficient incentives for competition, businesses collaborate on technology paths, standards and platforms in order to share the cost and risk of digital innovation and to exchange diverse knowledge. This organizational structure is the driving force behind digital innovation. Another strategy to promote innovation is to extend the audience and lower the threshold of innovation by incubating new breeds of organizations. As the most important form of organization for digital innovation, platform enterprises connect businesses directly with consumers, thereby expanding innovation's reach. Meanwhile, there has been an increase in the number of suppliers of intermediate and complementary products for digital innovation. They offer modularized and virtualized intermediate inputs for digital innovation, thus reducing the cost and barrier for businesses, particularly SMEs, to innovate. Suppliers of low-code and code-free development tools create basic development platforms to facilitate digital innovation with less effort and expense.

3.2 Heterogeneity of Industrial Organization for Digital Innovation

Digital innovation differs significantly from traditional innovation in terms of techno-economic paradigms, innovation process, outcomes and institutional systems. Those differences find expression in the corporate boundaries and relationships among competition and cooperation among firms.

Two-way platforms, as a form of industrial organization, have become a new vehicle for digital innovation. Platform enterprises have proliferated thanks to advancing digital technologies such as processors, the internet, broadband communication, programming languages, operating systems and cloud computing (Evans and Schmalensee, 2018). Connecting users/consumers with suppliers, platform enterprises have emerged as a new vehicle for digital innovations such as digital products, services and business models (Trabucchi et al., 2021). Platform enterprises are the driving forces behind digital innovation. Their ecosystems serve as experiment fields and vehicles for catalyzing digital innovation. There are two reasons why platforms have become vital innovation vehicles: First, their matchmaking function has decreased information asymmetry, expanded their audience and increased their digital innovation returns. As intermediary organizations, platforms have accumulated a large number of users under the network effect and created more opportunities for digital innovation to be presented to consumers. For instance, China's leading e-commerce platforms Alibaba, JD.com and Pinduoduo had 887 million, 580 million and 870 million annual active users, respectively, in 2021. Platforms have substantially reduced the costs of search and matching, enabling the results of digital innovation to be more efficiently matched with the requirements of users in a manner that magnifies economies of scale and innovation incentives. Second, the infrastructure functions of platform organizations provide complementary digital innovation assets to other innovators. The labyrinthine architecture of digital innovation necessitates substantial investments in complementary products, which platforms may provide in profusion to innovators in order to spur innovation. In addition to an inexhaustible data storage capacity, cloud computing platforms also provide intermediates and operating systems essential for software development. Third, platforms aggregate an ocean of essential knowledge for digital innovation. As mentioned earlier, digital innovation requires the exchange and integration of market demand, digital technology and industry expertise. Platforms bring together digital innovators like users, suppliers and makers of complementary products to serve as a hub for gathering knowledge. This makes it easier for participants to come up with new solutions through knowledge exchange.

Regarding the competition paradigm of innovative industrial organization, industrial ecosystem competition has supplanted corporate and product competition to become a new form of competition for digital innovation. Competition is essential to industrial organization and is the driving force behind continuous innovation (Belleflamme and Peitz, 2015). In contrast to traditional innovation, which features competition among products and companies, digital innovation involves both intra-ecosystem cooperation and inter-ecosystem competition. Firms within an ecosystem increase their success rate by overcoming the complexity and uncertainty of digital innovation through collaboration. Competition across ecosystems prevents monopolistic barriers from stifling innovation. In contrast to traditional competition among companies and products, the success of an innovation ecosystem is determined by the coordination among its internal groups rather than the competitiveness of individual companies and products. A digital innovation ecosystem typically consists of coordinators, suppliers and consumers. Coordinators create a digital innovation platform for core businesses that is more efficient than competitive ecosystems. Complementors provide the ecosystem with complementary products and enhance the diversity of digital innovations in the industrial ecosystem. Consumer preferences and behaviors determine the course of competition within an innovation ecosystem. The design of ecosystem architecture and the creation of governance systems are at the core of the digital innovation ecosystem in order to satisfy the needs of every group and maintain ecosystem coordination. An ideal innovation ecosystem, according to Tiwana (2018), should be simple, resilient, maintainable and evolvable. Good ecosystem governance assures the efficient allocation of decision-making rights, distribution and control mechanisms and pricing strategy, so that innovators can pursue their self-interest while contributing to the overall return of the innovation ecosystem.

In terms of innovative interactions among industrial organizations, the various modalities of interaction among end consumers or users and businesses are important for digital innovation. Successful innovation relies on being responsive to customer needs. Although traditional non-digital innovations are also concerned with user requirements, they are typically driven by manufacturers and technology providers, leaving users in a weak position to participate in the innovation process. What matters most for digital innovation is addressing the diverse and individualized requirements of users. In addition, the internet's pervasiveness has reduced the cost for users to partake in digital innovation. Von Hippel believes that, in addition to innovations led by traditional manufacturers, user-led free innovations will emerge as a new form of digital innovation. (Baldwin and Von Hippel, 2011; Von Hippel, 2017). User-business interaction has fueled digital innovation through such means as data analytics performed by businesses. Under this model, businesses collect extensive user data on product functions, performance and preferences, as well as purchase and use, via the internet, smart sensing and other new digital technologies in order to analyze user demand and design new digital products to meet consumer requirements. As an example, Asics has designed Evoride Orphe smart shoes with motion sensors to collect and transmit data, provide immediate feedback to users and recommend training program options. Another mode is community-based user-business interactions. In data analytics, consumers are passive data providers. With the advancement of internet technology and social networks, users have evolved from sporadic data sources to organized and proactive communities that interact with businesses and provide them with both user data and advice for digital innovation. Apple and Huawei, for instance, solicit feedback from their fan communities to enhance their products.The third mode is user-driven innovation. The purpose of the first two types of user-business interactions is for users to provide businesses with knowledge rather than partake in digital innovation. With R&D capabilities and extensive industry knowledge, some digital innovation recipients have transformed into suppliers. The Bao Steel Group, for example, worked relentlessly to develop digital capabilities that resulted in the incubation of BaoSight Software, transforming itself from a client into a supplier of digital solutions.

3.3 Strengths and Challenges of Industrial Organization for China's Digital Innovation

There is a relationship of interaction and coordinated development among industrial organization and digital innovation. Industrial organization for digital innovation is a result of systemic reorganization of traditional industrial organizations empowered with digital technology. Countries have different levels of industrial development, digital technology capabilities, market size and structure, leading to the heterogeneous evolution of industrial organization for digital innovation. China's industrial organization for digital innovation is distinctive in the following ways:

First, China's digital platform companies have exhibited remarkable multi-platform traits. China has the most complete internet infrastructure and the most numerous internet users worldwide. The large number of internet uses gives platform enterprises the advantage of acquiring a large user base under network effects (Xie and Wu, 2021; Rietveld and Schilling, 2021) and once the user base is large enough, platform enterprises tend to expand into new business domains. Baidu, Alibaba and Tencent, China's top three internet platforms, have operations in e-commerce, social networking, video and search engines. In contrast, platform enterprises in the United States are more focused on single business domains. Alibaba's business scope encompasses e-commerce, cloud computing, digital media and entertainment (Youku.com and Damai.cn), in addition to innovative services such as DingTalk, an enterprise-level communication and collaboration platform. According to Alibaba's financial report in 2021, 23% came from services other than its e-commerce platform, such as its catering and food delivery platform Ele.me, its online video streaming platform Youku.com and its travel ticket booking platform Fliggy. Amazon's business portfolio focuses on cloud computing and e-commerce. Comparing Tencent to Facebook and Baidu to Google reveals the multi-platform operations of Chinese digital innovation platforms.Multi-platform operations are both a boon and a burden for China's digital innovation. They generate economies of scale and economies of scope, enhancing the impetus for digital innovation. The multi-platform business mode amasses an ocean of diverse resources and multi-domain expertise, which assists digital innovation. For example, as an e-commerce titan, Alibaba leveraged its large user base, industry data and technological prowess to enter the industrial internet domain with its DingTalk platform, contributing to industrial digital innovation. Yet business diversification may give rise to monopoly under the network effect. The expansion of platform goliaths into myriad business segments will stifle innovation and their strategic behaviors such as self-preference and killer acquisition will impede innovation (Zhang, 2022).

The second characteristic of China's digital innovations for industrial applications is multi-path exploration and multi-platform competition. Digital innovation on the global stage is transitioning from consumer to industrial internet via industrial internet platforms (Shang and Jiang, 2021). China's vast industrial system, diverse industrial use cases and economies of scale developed in the consumer internet era have led to a unique mode of multi-path exploration and multi-platform competition with respect to industrial internet-based digital innovation. By their creators, industrial internet innovation platforms can be divided into two categories: Those created by consumer internet giants like Alibaba's DingTalk and those created by leading manufacturers like Sany Heavy Industry's RootCloud and XCMG's Hanyun industrial Internet platform; in the United States, manufacturing corporations play a larger role in industrial internet platforms. By their nature, industrial internet innovation platforms can be categorized into two types, namely generic and specialized platforms. These platforms exist side by side and compete with each other. Generic industrial internet platforms are designed to resolve generic industry issues such as production and logistical management. Examples in China include DingTalk by Alibaba and COSMOPlat by Haier. In contrast, manufacturing companies in the US develop specialized platforms to facilitate digitalization and innovation in specific industrial sectors, such as GE's Predix platform.China adopted multi-path exploration and multi-platform competition due to the following reasons: First, Chinese manufacturers of various sizes have a strong demand for digitalization, which provides ample market space for multi-path digital product and service innovations. Second, some consumer internet platforms are transformed into industrial internet platforms with the support of user base, capital and technology. Large manufacturing enterprises with diverse operations provide digital innovation with broad internal market opportunities, giving rise to specialized industrial internet platforms such as Baosight Software by Baosteel and Rootcloud Technology by Sany Heavy Industry. By adopting the industrial internet, businesses with diverse technological capabilities and market positions have expanded the scope of disruptive innovations. China's industrial internet platforms are more focused on digital applications for specific sectors and unlike their US counterparts, the majority of those applications are superficial integrations based on platform architectures. Numerous platforms rely on external sources for critical components and technologies, including data analytics models, data collection systems and platforms for software development. Their external dependence poses a threat to independent industrial digital innovations.

4. Institutional Groundwork for Digital Innovation

4.1 Institutional Impetus for Digital Innovation

According to neoclassical economics, enterprises are the primary R&D actors. The innovation system, on the other hand, centers around non-corporate innovators such as universities and R&D institutions, as well as interactions among these entities and businesses under market and non-market norms. According to empirical research, the innovation system determines the long-term technological innovation performance of a country and its industries (Edquist, 1997). Digital innovation is a complex process and system that incorporates science, generic and specialized technologies, processes, skills and other knowledge and abilities, as well as individuals, equipment, software, digital infrastructure and use cases. Businesses are the source of technological advancement. Businesses are responsible for integrating digital innovation factors and offering digital products and services. Nevertheless, market forces alone are inadequate and subject to market and system failures. Universities, research institutions and other non-corporate innovators and non-market innovation mechanisms besides the price mechanism also contribute complementary knowledge and factors. In comparison to other forms of innovation, digital innovation is novel, multi-faceted and sophisticated (Bogers et al., 2022). In other words, digital innovation will far surpass the knowledge boundary of businesses, compelling them to acquire knowledge from universities, national laboratories and other public research institutions. Frequent interactions with these institutions are important to maintain vibrant digital innovations. International competition for digital innovation, despite appearing to be at the level of corporations, is largely dependent on knowledge production by non-corporate entities and the capacity of corporations to assimilate and commercialize such knowledge.

The innovation system promotes digital innovation by providing firms with public knowledge in areas in which they lack incentive or competence to invest. Scientific research, generic digital technologies and digital standards are vulnerable to underinvestment and market supply failures due to their non-competitive consumption and varying levels of non-exclusiveness. Hence, they must be provided by universities, generic technology research institutions, suppliers of basic technologies, national laboratories and other public R&D institutions. Effective interactions among innovation entities facilitate the flow, combination and integration of digital knowledge in the innovation system. Universities and other public R&D institutions produce digital knowledge and their scientific research findings are commercialized to increase productivity. After the Dartmouth Conference in 1956, for instance, Professor McCarthy and Professor Minsky founded the first AI laboratory in the world at the Massachusetts Institute of Technology (MIT), which is now known as the MIT Computer Science and Artificial Intelligence Laboratory (CSAIL). Since then, AI as a discipline has witnessed rapid growth. With rising AI sophistication, IBM began to increase sponsorships to and collaborative R&D with academia after 1983, marking a start to commercialize AI research. AI research and commercialization have been accelerated by the growing adoption of AI by businesses, particularly tech firms. While universities plant the roots of AI knowledge, businesses participate in the development of technology in collaboration with universities and serve as the vehicle for the realization of AI capabilities. In addition to collaborative research among universities and businesses and contract research programs conducted by public research institutions on behalf of their corporate clients, the academic entrepreneurship of universities, national laboratories and other public R&D institutions is an important means of commercializing digital technologies. The commercialization of a significant portion of the critical technologies that have propelled the United States to the forefront of the digital economy is attributable to the entrepreneurial whims of university professors or researchers at public research institutions (Mazzucato, 2015). Through the technology and human resources markets, corporations deepen the integration of digital technologies and knowledge. Alibaba, for example, acquired C-Sky Microsystems, a chipmaker, while Google acquired DeepMind, a top AI lab. The movement of elite AI and blockchain engineers and R&D administrators among internet platform companies and specialized tech firms has enhanced the diffusion, recombination and innovation of digital technology. The innovation system also supports digital innovation through the cultivation of digital professionals for businesses. Universities provide digital technology courses and curricula that teach students how to use digital tools for data extraction, digital fitting and deep learning, as well as skills for R&D and implementation of digital technology. The US has highlighted the ability of scientists and research employees to use digital tools as a critical component of the national digital strategy (OECD, 2019).

4.2 Heterogeneity of the Digital Innovation System

Digital innovations are different from existing technologies in terms of the form of technologies and products. Moreover, digital technologies are characterized by non-traditional technological paradigms. In addition to the general traits, an innovation system must also possess unique structures and functions to catalyze digital innovations.

Market failure poses a threat to the availability of scientific research, generic technologies and other forms of public domain knowledge. In accordance with the digital innovation system, the structure and organization of knowledge production must be adapted to satisfy the requirements of the digital technology paradigm. First, digital infrastructure functions as an innovation vehicle for non-traditional, non-corporate innovation entities, such as research universities and national laboratories. In Tianjin, Shenzhen, Guangzhou, Changsha and Jinan, for instance, the Ministry of Science and Technology (MOST) has established eight national supercomputing centers for digital innovations in genetic engineering, industrial design and simulation, aviation and aerospace, weather and climate forecast, maritime environment simulation and the processing of aerial remote sensing data. These supercomputing centers are all public institutions that provide public services. The first and fastest exascale supercomputer in the world, Frontier, is hosted by the US Department of Energy's Oak Ridge Leadership Computing Facility. Some digital infrastructures necessitate substantial capital and human inputs for high-risk R&D projects and their supply is hampered by market failure. Infrastructure risks and costs are borne by public non-profit organizations, which serve as the engine of digital innovation.

The production of public goods must be reorganized based on the paradigms of digital technology. Curiosity-driven research paradigms under academic autonomy have advanced basic research in specialized disciplines (Partha and David, 1994), which is incompatible with the multi-disciplinary paradigm of digital innovation. AI and other digital technologies are generic or multi-purpose technologies and their integration with other scientific knowledge and technologies provides a crucial mechanism for advancing digital science and innovation. Increasingly, businesses derive their fundamental competencies from their capacity to integrate digital and other technologies. Automakers, for instance, rely on machinery and electrical engineering as their primary technologies. In the context of digitalization, however, software engineering and AI skills are equally important. Demand for technology integration motivates universities to conduct cross-disciplinary education and research. Numerous research universities of world-class caliber have already reorganized scientific research for digital innovation. There has been a recent uptick in the number of inter-disciplinary research and educational programs offered by prestigious research universities like MIT in fields such as computer science, biology, economics and data science.

The digital innovation system is well-positioned to overcome the failures of digital innovation system. First, instead of the traditional linear paradigm, interactions among research institutions and businesses take the form of ecosystems or networks. The effects of digital technology on product architecture are twofold. On the one hand, the boundary among technology, product and sector has blurred. New combinations of technologies and products from different domains have increased the sophistication of product architecture. On the other hand, digital technology has increased the component modularization and the standardization of component interfaces. Under the product architecture enabled by digital technology, companies must incorporate a vast array of innovation factors from universities, research institutions and corporate partners. Such integration has increased the division of work among businesses, universities and research institutions for knowledge creation. Given the dual effects of digital technology on product architecture, the innovation system should provide businesses as the ultimate integrators of knowledge with access to specialized public knowledge and digital infrastructure, which cannot be effectively provided under the market mechanism. Moreover, the innovation system gathers different kinds of knowledge through distinct ecosystem structures and network modalities for incorporation by firms. Contract and collaborative research and development, as well as patent licensing, are traditional methods for commercializing R&D results. It takes a more embedded approach for firms to integrate scientific research, generic technologies and other knowledge and services dispersed throughout the innovation system. By creating open-source communities, for instance, businesses attract R&D personnel and laboratories of public research institutions to participate in digital innovation. In contrast to the traditional mode of cooperation among businesses and universities, the open-source innovation ecosystem involves frequent interactions among businesses and researchers from various universities or other public research institutions. In this open ecosystem of mutual benefit, companies no longer integrate the knowledge and capabilities of research institutions under formal contracts, rules and control (Autio, 2022). Researchers participate in the innovation ecosystems established by companies based on non-monetary considerations such as reputation and access to knowledge (Lerner et al., 2006).

Despite the fact that universities and other public research institutions provide businesses and the general public with digital products and services in a relatively free and open manner, the unique technology paradigm of digital innovation has complicated the institutional design of interactions among industries, universities and research institutions. Unlike physical products, digital products and services tend to have exorbitant fixed costs and "first replication" costs, but the marginal cost of reproduction is nearly zero (Goldfarb and Tucker, 2019). Hence, universities, national laboratories and other public research institutions should provide the corporate sector with basic research results, generic technologies such as data, images, software, codes, tools, databases, algorithms and statistical models as freely and non-exclusively as possible in order to maximize the social value of research results from public research institutions.

However, not all digital knowledge produced by the public sector can be utilized directly by businesses. In many instances, firms have to make additional investment and development of technologies and products from the public sector. If businesses re-innovating digital technologies from the public sector are granted protection of their innovation results, including intellectual property rights, business secrets and human resource terms, and thus receive sufficient innovation rents (He et al., 2012), the free supply of technological research becomes socially optimal because it ensures the public-interest nature of technological research without impeding corporate re-innovation. In the absence of institutional mechanisms or effective strategic activities to safeguard their reinvestment in innovation, businesses may encounter a paradoxical situation with regard to the transfer of technological research outcomes from the public sector to both businesses and the general public. If technological research findings from the public sector are exclusively licensed to specific enterprises, it means that those enterprises will hold a monopoly over technological research outcomes originating from the public sector, which is funded by the collective taxpayer base. Nonetheless, if public technological research results are licensed to particular enterprises on a non-exclusive basis, it may not provide adequate motivation for corporate reinvestment in the products or services. In order to resolve this predicament, decision-makers must achieve an equilibrium among the communal nature of technological investigation and inducements for commercial reinvestment. Hence, the US National Academies of Sciences, Engineering and Medicine adopted the following principle regarding the commercialization of technological research findings in the digital sphere: Data and metadata generated by federal laboratories must be provided to individuals, researchers and companies in a free and open manner as much as possible under the existing laws and policies. In cases where companies require significant additional investment to commercialize digital innovation and the final products are easily imitable, federal laboratories should allow those companies to use public technological research results on an appropriately exclusive basis to incentivize corporate investment and innovation (National Academy of Sciences, Engineering and Medicine, 2021).

4.3 Unique Strengths and Challenges of China's Digital Innovation System

There are similarities and differences among the innovation systems of countries and of sectors within the same country (Mowery and Nelson, 1999). The differences are the key to understanding the varying levels of industrial development across nations. For China to become a digital innovation powerhouse, it must develop a digital innovation system that satisfies the general requirements of the technological paradigm for digital innovation and maximizes its institutional advantages. The heterogeneity of China's digital innovation system rests at the heart of the country's digital innovation strengths.

Flexibility is the most distinctive feature of China's digital innovation system. After the 1950s, the United States government increased funding for basic research by universities, referring to the European system of research universities. Universities were given enough academic autonomy to allow them to stay focused on basic research (Nelson, 1997). At the same time, national laboratories and manufacturing innovation centers received some autonomy under independent committees and other governing bodies. The roles and responsibilities of public research institutions and the boundary of their collaboration with the business community are explicitly defined by law, limiting their flexibility. China has only established universities and public research institutions such as the Chinese Academy of Sciences (CAS) in such a context as a late-moving country. Due to the lack of technological capabilities of Chinese firms at the outset of the reform era, Chinese universities and CAS became directly involved in industrial activities by establishing affiliated enterprises (Eun et al., 2006). Chinese universities and research institutions have a national mandate to keep pace with advanced nations. The government holds great control over the governance and priorities of universities and research institutions, making them more flexible than their counterparts in the developed world. The flexibility of China's innovation system and the innovators' national mandate constitute a distinct advantage for digital innovation: By modifying the functional boundary of existing innovators or establishing new public research institutions, China is able to prepare for and address corporate demand for digital innovation, so as to develop diversified resources and innovators in strategic domains of digital technology. Such flexibility, if not properly regulated, could be detrimental to the missions and functions of public research institutions. Some universities and research institutions would be overly involved in the commercialization of digital technology, or license or transfer technologies that should be in the public domain to specific companies, jeopardizing the public-interest nature of basic research and generic technologies.

As a further potential benefit of China's digital innovation system, the Chinese government can expedite the integration and application of digital technologies by coordinating the actions of innovators. Digital technology, and innovation platforms in particular are distinguished by a high level of technological sophistication (Cusumano et al., 2019). The government-driven innovation system offers the institutional strength of unified organization and coordination for the development of an industry-wide technology standard or technology architecture. In the 3G era, China's less advanced TD-SCDMA standard prevailed over the United States' more powerful WiMAX standard because the Chinese government coordinated technology, standard and industry development based on the IMT-Advanced and major technology research programs, bringing together a range of innovators based on China's independent TD-SCDMA standard. Included are institutions for basic research, the China Academy of Information and Communications Technology (CAICT) for generic technologies and testing, telecom operators for the commercialization architecture and business deployment and equipment manufacturers for systems and components. Their collaboration resulted in China's own 4G standard. In the absence of policy incentives, US telecom operators such as AT&T were hesitant to commercialize the WiMAX standard and coordination within the WiMAX group, which included Qualcomm and Intel, was inadequate. As a result, a complete WiMAX industrial chain failed to establish itself in the United States, preventing the WiMAX standard from becoming the predominant 4G standard (see Table 1). Although academics and policymakers generally refer to digital, smart and internet-based technologies as digital technologies, digital technologies vary in their paradigms across domains. As an enabling technology, AI has vast application potentials in a variety of fields. In this situation, it is crucial for companies and other innovators to focus on their respective disciplines of research rather than acting in unison. Similar to mobile communication technology, the industrial internet requires well-timed government intervention and coordination among universities, research institutions and businesses to form a few or a single technology architecture or standard in order to avoid the complexity of multiple technology paths. In addition to the business sector, digital technology has vast application possibilities in the government, energy, education, healthcare and other public sectors. The government may fully leverage the digital opportunities of these sectors and public research institutions (national laboratories and supercomputing centers, for example, are the primary vehicles of supercomputing capabilities) in order to provide diverse and cutting-edge technologies for China's digital innovation in myriad use cases. While maximizing our organizational and coordination strengths, we should not let our whole-nation system to be utilized excessively to suppress innovation.

Table 1: Comparison of Digital Innovation Organizations in China and the United States

Organizational dimension	Chinese uniqueness	Aspect of comparison	China	United States
Corporate organization	Intensive and institutionalized internal competition and cooperation	Intensity of internal competition and cooperation for social network platforms	In 2010, Tencent set up three R&D teams to develop three instant messaging products at the same time, including Mobile QQ, QQ Address Book and WeChat. It was decided in the early stage of product development that all the three products would be launched into the market. In the process of developing the three products, Tencent took steps to institutionalize its internal competition and cooperation, which is a primary reason behind WeChat as an innovative instant messenger app (Murmann and Zhu, 2012).	Some large US firms have introduced an internal competition and cooperation system into their subsidiaries and business departments for parallel product development. Under the principle of "parallel development and survival of the best", internal competition only exists in the parallel development stage. When parallel development enters the next stage with a clear outlook of commercialization for the new product under different technology paths, the company will end internal competition and bring together different development teams with their early-stage exploration and knowledge to focus on a certain product or technology and launch it into the market.
	Hierarchical culture and customs	Direction of organizational restructuring for large digital innovation companies	As an internet company, Xiaomi used to pride itself on flat and streamlined management, no KPIs and human-based corporate management. However, the company is returning to a hierarchical system. In the Chinese context, the flat organizational management mode has led to two problems: First, the strong position of departments has made internal communication and collaboration more difficult. Second, once a manager leaves, it is hard to find someone to fill the gap immediately. Given these problems, Xiaomi decided to shift from the flat organization to the traditional hierarchical system.	IBM has reorganized itself into a reconfigurable organization consisting of a stable part and a variable part. Among them, the stable part encompasses basic processes such as financial affairs and customer relations. These processes will continuously improve, but are shared throughout the company. The variable part encompasses re-organizing innovation and decision-making teams responsible for allocating resources and setting priorities. Thanks to the reconfigurable structure, the activity modules (innovation teams) can be adjusted and coupled to address emerging innovation opportunities.

Table 1 Continued

Organizational dimension	Chinese uniqueness	Aspect of comparison	China	United States
Industrial organization	Multiplatform characteristics of digital enterprises	Business scope of e-commerce and social media	Aside from e-commerce platforms, Alibaba also operates digital media and entertainment platforms such as Youku.com and Damai.cn, as well as innovation business platforms for the industrial sector such as DingTalk. Among them, business revenues from sources other than e-commerce platforms, including Ele.me, Youku and Fliggy account for 23% of Alibaba's total revenues. Tencent's business scope includes digital entertainment such as gaming platforms and video and music services, social network platforms like QQ and WeChat and media platforms such as Tencent News.	Amazon, the largest e-commerce company in the US, is focused on e-commerce and cloud computing platforms. Its cross-sectoral and multi-platform business operations pale in comparison with comparable platform companies from China such as Alibaba. Compared with Tencent's multi-platform operation, the US social media company Facebook's business scope is also highly focused on social media with less obvious cross-sectoral and multi-platform traits.
	Multi-path exploration and multi-entity competition	Competition among industrial internet platforms	Some industrial internet platforms in China are created by consumer internet platforms such as Alibaba's DingTalk and others are created by leading manufacturers such as Sany Heavy Industry's RootCloud. They include generic industrial internet platforms such as Alibaba's DingTalk and dedicated industrial internet platforms like Hodo Industrial Internet Platform.	As a leading industrial internet company in the US, GE has developed the Predix industrial internet platform as a generic platform of underlying manufacturing technologies. There is no sign that traditional consumer internet platforms in the US such as Amazon and Facebook have forayed into the industrial internet business. Compared with China, multi-technology exploration and multi-entity competition in the field of industrial internet are less obvious in the US.
Innovation system	Flexibility of non-corporate innovation entities	Functional boundary of universities	Chinese innovators are highly focused on catching up with industry leaders and the government is able to influence universities. Aside from basic research, Chinese universities also have a strong focus on technological innovation and industrialization (Eun et al., 2006). That is to say, the orientation of Chinese universities is more flexible with a stronger tendency to commercialize R&D results.	After the World War II, the US federal government increased financial support to research universities and introduced legislation on academic autonomy and discretion to keep universities focused on basic research (Nelson, 1997). Compared with their counterparts in China, research universities in the US are more focused on basic research since the commercialization of R&D results is subject to more institutional constraints (Stephen, 2015).
	Government cross-entity coordination in non-market interactions	Progress in mobile communication technologies	In the 3G era, the Chinese government created a system for integrated progress in technology, standard and industry based on IMT-Advanced and major research programs. While universities carried out basic research, the CAICT focused on generic technologies and testing, telecom operators played a leading role in commercial deployment and equipment vendors developed systems and components. Their synergy has contributed to China's successful development of the mainstream 4G standard.	In the absence of policy incentives during the 3G era, US telecom operators such as AT&T were hesitant to commercialize the WiMAX standard and coordination within the WiMAX group, which included Qualcomm and Intel, was inadequate. As a result, a complete WiMAX industrial chain failed to establish itself in the United States, preventing the WiMAX standard from becoming the predominant 4G standard.

5. Policy Suggestions

China's corporate organization, industrial organization and innovation system are distinct from those of the United States and other Western market economies. Although these characteristics present organizational advantages for China's digital innovation, their underlying norms may pose obstacles and impediments to China's digital innovation breakthroughs. Policymakers should maximize China's organizational advantage for digital innovation, leverage its organizational strengths and address any organizational disadvantages. Based on this policy approach, this study suggests reshaping China's digital innovation policy system in terms of corporate organization, industrial organization and innovation system.

(i) Corporate organization: China should promote its best local practices for digital innovation organization and management in light of its unique national conditions for digital innovation to simultaneously make up for the imperfections of Industry 2.0, popularize Industry 3.0 and experiment with Industry 4.0. It is suggested, for instance, to organize competitions for the best digital innovation management practices, to appoint domestic think tanks and other third-party research institutions to conduct regular surveys, to increase adaptability for digital innovation and to identify local organizational forms and patterns and increase their diffusion to local businesses with digital innovation potentials.

Second, SOEs should reduce management hierarchies and make structural adjustments at the headquarters level and within the affiliates' internal organization. Priority should be placed on establishing a non-hierarchical and decentralized organizational structure as well as a new organizational culture for newly established SOE affiliates or departments for digital innovation.

Lastly, SOEs and their digital innovation affiliates and departments should develop and implement a trial-and-error mechanism to encourage their management and research personnel to identify and leverage digital innovation opportunities. There should be a set of standards for liability exemptions based on the pace of iteration and other distinguishing characteristics of digital products, digital integration and digital innovations. SOEs employees will conduct digital innovation with confidence if they are aware of their responsibilities and risks.

(ii) Industrial organization: The government should expedite the development of a national unified digital market and strengthen multi-path exploration and multi-entity competition strategies for digital innovation. Regional fragmentation of the digital market has prevented China from nurturing digital innovation. Local authorities should be dissuaded from impeding market competition in the development of smart cities, digital government and a digital economy. The government should establish a set of rules for the evaluation of fair competition in the digital economy. Digital innovation should be encouraged by a nationally unified digital market with equitable competition. A digital technology security certification system should be implemented to prevent unfair competition resulting from digital security certification and to level the playing field for all digital innovation businesses.

Another priority is to strengthen anti-monopoly policy and law enforcement in order to promote the free flow of data and interconnectivity among digital solutions and platforms, as well as to achieve an optimal policy balance among economies of scale, economies of range and platform monopoly. Anti-monopoly measures should address the monopolistic risks posed by platform companies that force consumer choice and refuse to deal, among other monopolistic practices.

Lastly, digital innovation companies, particularly start-ups, small businesses and microbusinesses, should be provided with policy guidance on innovations such as data-based decision-making models and industrial software in order to acquire choke-point technologies for digital innovation. China's digital innovations are focused on integration on the application side and innovations in critical areas such as the analytics model, data collection and software are insufficient. This disparity should be addressed through policy.

(iii) Digital technology innovation system: The government should encourage innovators, especially non-corporate innovators, with a mandate. As a unique institutional strength, China is able to mobilize innovators to accomplish innovation projects outside their boundary of tasks. It may even establish a public research institution with a special mandate in a short time to address the structural and functional deficiencies of the industrial innovation system. China may create public research institutions in areas where innovators lack the incentive and capability to achieve disruptive innovations. The structural deficiencies of China's digital innovation system can be compensated with its organizational efficiency.

Second, there should be more coordinations among the government and enterprises, among public research institutions and among enterprises in certain domains. The government may coordinate technology, standards and industry development similar to its approach for the IMT-2020. It is suggested to foster institutional strength for digital innovation by promoting consensus and synergy among universities, research institutions, standard organizations, core component and software suppliers, platform integrators and users.

Lastly, the government should increase the protection of intellectual property rights for basic research from universities, generic technologies from research institutions and the commercialization of technologies by businesses. It is also important to develop a digital technology market that operates efficiently and cost effectively (Arora et al., 2001) to promote the flow, diffusion and recombination of digital knowledge across universities, research institutions and businesses.

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