# *Cultivating Regional Innovation Ecosystems in the Digital Age: Case Studies of Four Cites in China*

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*This paper explores the cultivation paths of innovation ecosystems in the digital age by constructing a theoretical framework consisting of innovators, elements of innovation, platforms, and digital governance. Four cities in China, Shenzhen, Hangzhou, Xuzhou, and Weifang, were selected as in-depth case studies. Findings revealed that: 1) regions with "head enterprises" and a strong industrial base achieve a competitive advantage via the synergy of digital industrialization and industrial digitalization; 2) digital technology pioneer regions can adopt digital industrialization; 3) regions with a strong industrial base and traditional manufacturing industries can prioritize industrial digitalization; and 4) manufacturing regions with a large number of SMEs can combine industrial digitalization and digital value. This study provides theoretical and practical value for the cultivation of regional innovation ecosystems.*

**Keywords:** Digital industrialization, industrial digitalization, regional innovation ecosystem, digital transformation

## Introduction

The digital economy, with the Internet of Things (IoT), big data, cloud computing, artificial intelligence (AI), blockchain, and other new-generation information technologies, is a new driving force for economic development (Lee et al., 2018; Yoo et al., 2010). As a new element of production, digital technology reshapes methods of value co-creation among innovators, expanding theories of innovation towards digital innovation ecosystems. (Nambisan et al.,

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2017; Goldfarb & Tucker, 2019; Beltagui et al., 2020).

An innovation ecosystem in the digital age is emphasizes the synergy and cooperation between innovators. It not only addresses the value co-creation through innovation, but also demonstrates convergence, scalability, self-growth, and modularity (Gomes et al., 2018; Jacobides et al., 2018; Zhang et al., 2021). The concept of the innovation ecosystem, introduced in the US in 2004, is fundamental for national innovation capabilities. The EU concerns a strategy aiming for a digital single market to achieve faster development. China, as a traditional manufacturing country, also regards the digital economy an important means to enhance its economic growth (Saleh, 2020).

Studies on digital innovation ecosystem is increasing (Krishna & Sha, 2015), from the aspects of connotation characteristics (Yu, 2017), capacity (Yang, 2020) and governance (Wei, 2021). Innovation ecosystem, for both digital age and as well as globalized world where S&T factors take center stage, are based on research based universities, R&D and S&T institutions, S&T output, startups and incubators, advances in telecommunications and ICT networks. Nevertheless, research gaps remain regarding the cultivation path for regional innovation ecosystems.

Based on the above background, our research question is "*how to cultivate innovation ecosystems in different regions in the digital age?*". In this paper, we propose a theoretical framework based on a literature review and in-depth case studies of four cities in China. We then discuss the cultivation paths of regional innovation ecosystems and generate propositions. Theoretical and practical implications are addressed along with a future research agenda.

## Literature Review

### Digital Transformation in China

In recent years, China has witnesses rapid digital transformation. Table 1 outlines the major policies issued by the Chinese government in the last decade to promote digitalization.

**TABLE 1**
**Policies to promote digital transformation in China**

| Year | Policy | Highlight |
|---|---|---|
| 2012 | Report of the 18th National Congress of the Communist Party of China | To vigorously promote the integrated development of informationization and industrialization |
| 2013 | Implementation Scheme of Broadband China Strategy | To provide a development foundation for digitalization |
| 2015 | Made in China 2050（ | To accelerate the deep integration of the new generation of information technology and manufacturing industry, and promote industrial transformation and upgrading |
| 2016 | Outline of National Innovation-Driven Development Strategy | To emphasize that innovation-driven means innovation becomes the first driving force to lead development |
| 2017 | Work report of the Chinese Government | To provide definition of the term digital economy |

| | | |
|---|---|---|
| 2018 | Industrial Internet Development Action Plan | To implement the industrial Internet innovation development strategy and promote the deep integration of the real economy and the digital economy |
| 2019 | Guiding Opinions on Promoting the Standardized and Healthy Development of Platform Economy | To promote the development of digital economy industry |
| 2021 | The 14th Five-Year Plan | To accelerate digital development and building a digital China |

**Source:** Complied by the authors

Digital transformation can mean: changes based on digital technology with data as the core; product and service transformation; and process optimization and reorganization (Ardolino et al., 2018). It can reduce information asymmetries, lower costs, and help companies to improve quality and efficiency (Nadkarni & Reinhard, 2020; Reinartz,2017; Yun et al., 2016). New technologies such as big data, AI, and blockchain can create new jobs, demand, and industrial chain (Saberi et al., 2019; Fran et al., 2019). Indeed, digital transformation integrates production and service, driving industrial efficiency and promoting cross-border industrial integration (Nambisan et al. 2019).

There are two features of digital transformation. First, data intervene during digital transformation can be rapidly gathered and iterated to accumulate advantages and maximize value (Verhoef et al. 2021). Second, digital technologies can integrate and empower traditional industries, changing the industry (Demirkan et al., 2016).

**Innovation Ecosystems in the Digital Age**

An innovation ecosystem is an evolving collection of actors, behaviors, technologies, products, institutions, and relationships (Chae, 2019). It involves nonlinear interactions, symbiotic coupling, competition, and cooperation (Nambisan et al., 2017). The digital innovation process is much more open and complex, with dynamic and flexible innovation actors, and the process and output of innovation are intertwined (Nambisan et al., 2017). Digital technologies change the competition and cooperation between companies in the ecosystems (Gawer et al., 2014; Boudreau and Jeppesen, 2019). Governance structure of innovation also needs to be concerned during digital transformation (Constantinides et al., 2018; Wei et al., 2021).

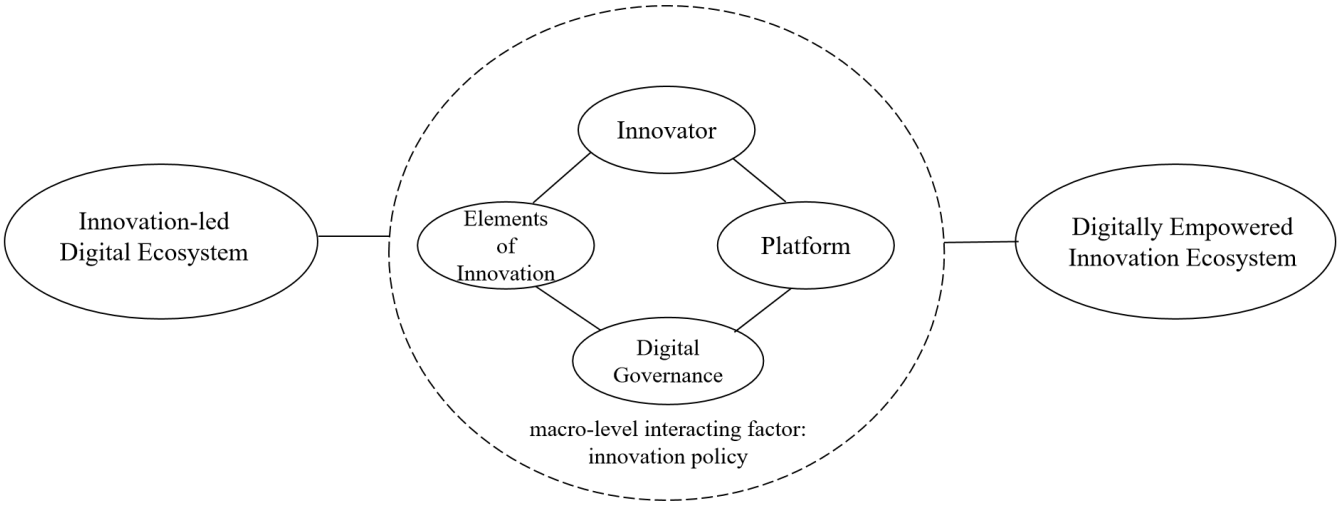
Innovation ecosystem in the digital age is regarded as a business model innovation or a digital innovation strategy (Täuscher & Laudien, 2018; Bharadwaj et al., 2013). In this paper, we regard innovation ecosystems as a combination of two views. First, it is digital-related innovation, a complex system composed of a digital innovator, data elements, users, and other digital users to achieve open information sharing and cross-industry and cross-border cooperation and innovation (Helfat & Raubitschek, 2018; Izaskun et al., 2020; Zhang, 2021). It is to promote the innovative generation, application, and diffusion of digital technologies to achieve value-added innovation (Adner et al., 2016), and to analyze of data by the Information and Communication Technology (ICT) industry to create digital products (Liu et al., 2020). Second, an innovation ecosystem means the optimization and reconstruction of innovator behavior using digital technologies (Xu, 2020). Through digital technologies, it is possible to

integrate the innovator, the public, and industry, as well as innovation resources (Ramezani & Camarinha,2020). Therefore, digitally empowered innovation ecosystems, in which digital processes and the innovator are deeply connected around a common core value proposition, enable innovation in industry (Zhang et al., 2021; Gupta et al., 2019). Accordingly, an efficient way is to apply digital technologies in traditional industrial sectors (Liu et al., 2020).

**Research Gap Identification and Theoretical Framework**

This study draws upon the following important literature: Adner's (2017) categorization of digital innovation ecosystems as innovation elements, participating actors, and inter-actor relationships; Zhang's (2021) five dimensions of innovator, structure, system, function, and evolution; Liu's (2020) analytical framework of innovation support, innovation process, and innovation output; and Teece's (2018) Profiting from Innovation (PFI) analysis. Our conceptual framework is shown in Figure 1.

**FIGURE 1**
**Diagram of Theoretical Framework**




**Source:** Created by the authors

As shown in Figure 1, the first component is the innovator. Innovators can be enterprises (Adner, 2016), universities (Krishna, 2019; Radicic et al., 2020), R&D organizations (Beltagui et al., 2020), knowledge institutions (Bittencourt et al., 2021), and technology platforms (Gawer, 2014). In the context of China, knowledge institutions have become an important source of scientific and technological innovation achievements in the digital transformation. Indeed they lead and participate in the construction of major innovation platforms such as regional key laboratories, which provide important knowledge and technical support for the optimization and upgrading of regional industrial structure. Universities are the main training ground for digital economy talents. In 2021, universities across China invested 34.2 USD billion in R&D. Besides cultivating talents in the digital economy, universities actively carry out innovative research, continuously making technological breakthroughs. Meanwhile, universities and enterprises build partnership in China, to realize complementary advantages

and collaborative innovation. The university-industry partnership breaks through the key core technologies that restrict industrial development, and accelerates the transfer and transformation of scientific and technological achievements.

The second component concerns the elements of innovation, namely digital resources, digital technologies, and digital infrastructure (Nambisan et al., 2017). These elements can be optimized to nurture new business models (Chen, 2020). The third component is the platform. Information exchange, user feedback, and iterative renewal of innovation elements between innovators in the innovation ecosystem are carried out via innovation carriers. Additionally, the expansion of platform carriers drives the development of the innovation ecosystem (Kim and Kim, 2020; Li et al., 2020; Liang et al., 2022; Yun et al., 2022). The fourth component is digital governance, concerning how to design reasonable solutions to facilitate value co-creation (Teece, 2018).

As for the external environment, policies can effectively promote cooperation among innovators, reducing transaction costs and maximizing the innovation vitality of innovators. Under the dual effects of innovation policy guidance and motivation, the undesirable factors are further improved and optimized, laying the foundation for high-quality original innovation outcomes to be introduced into the industry. This can also guarantee the orderly development of the innovation ecosystem. Meanwhile, technology conflicts and controversies between Chinese and USA firms in digital and telecommunications advanced technology has come into sharp focus in the last 3-4 years. This has stimulated China to formulate its own digital technology development strategy, increasing investment in digital technology R&D and realizing the independence and mutual catch-up of digital technology. In the era of digital economy, data resources and digital technology play a key role in economic development, and innovation drive is the core feature of digital economy development. Accordingly, policy support and core digital technology development become important in China.

## Research Methodology

Our research adopts a multi-case study method to perform theoretical construction and explain highly complex multilevel phenomena (Yin, 2013; Eisenhardt, 1989). With a focus on the cultivation paths of regional innovation ecosystems in the digital age, this study aims to answer the “how” question. We selected four cities in China for in-depth investigation. China has highly complex and specific institutional and market environment, and the rapid development of its digital innovation ecosystem, which can help to enrich existing theory (Teece, 2018). Furthermore, because ecosystems often involve multiple players and require discipline for all stakeholders, China, being in a phase of transition, has provided a favorable environment for exploring the development path of regional innovation ecosystems as a consequence of the government’s policy support for the pursuit of digital economy development strategies (Gorwa, 2019; Schmeiss et al., 2019; Ma et al., 2019; Huang et al., 2020).

The profile of the four cases are shown in Table 2. They cover both developed and less developed regions, which demonstrate active and successful digital transformation, in line with the theme of the research.

**TABLE 2**

**Overview of the Four Cases**

| *City* | *Representative companies* | *Overview* |
|---|---|---|
| Shenzhen | Huawei, Tencent, Build your Dreams (BYD) | A special economic zone; A center of science and technology innovation; GDP of RMB 3,066.485 billion in 2021 |
| Hangzhou | Alibaba, GEELY, Hikvision | Rapid development in AI, integrated circuit, and electronic information product manufacturing industries. GDP of RMB 1,810.9 billion in 2021. |
| Xuzhou | XCMG, Saimo | The capital of China's construction machinery; GDP of RMB 811.744 billion in 2021. |
| Weifang | Weichai, GoerTek | Power equipment industry cluster; A pilot city for "Science and Technology Innovation in China". GDP of RMB 701.06 billion in 2021. |

**Source:** Complied by the authors

Data were collected from March 2018 to June 2022. Primary data were obtained through semi-structured interviews with government officials, corporate executives, technical staff, and target users involved in the cases. Each interview lasted 1 hour. Data then went through content analysis. Based on the principle of validation by triangulation, secondary data were also analyzed, which include industry reports, government policies and company archival records.

## Case Analysis

With rapid development, China's digital economy reached 5.18 trillion USD, accounting for 36.2% of the country's GDP in 2019. The total value of digital platform was 2.02 trillion USD, accounting for 22.5% of the world in 2019. In 2021, China made a new breakthrough in terms of the digital economy, generating 7.13 trillion USD output value, representing 39.8% of the country's GDP. Among them, the ICT industries demonstrate a major position. Regional innovation ecosystems are formed alongside digital transformation. The following cases are analyzed in terms of the innovator, elements of innovation, platform, and digital governance.

### Case One: Shenzhen City

Shenzhen is located in Guangdong Province in south China. In 2021, the value of Shenzhen's core digital economy industry was more than RMB 900 billion. Shenzhen has built digital economy industry clusters such as software and information services, digital creativity, intelligent network-connected vehicles, and intelligent robots. As for policies, Shenzhen issued the Implementation Plan for Innovation and Development of Digital Economy Industry in 2021, which facilitated the actively collaboration among local universities, research institutes, and enterprises. Meanwhile, Several Measures to Promote the High-quality Development of Software Industry in Shenzhen focused on the development of basic software, industrial software, new technology platform software and large-scale industry general software, which

are fundamental to a technological innovation system.

*Innovator*

As a leading region in China's digital economy, led by the clusters of top ICT companies such as Huawei, Tencent, Zhongxing Telecom Equipment (ZTE), and Da Jiang Innovations (DJI), Shenzhen was home to 21,000 high-tech enterprises. The top companies according to the annual turnover in 2021 are shown in Table 3.

**Table 3**
**The top companies in Shenzhen in 2021**

| Company | Annual Turnover (USD million) | R&D investment (USD million) | Technical engineer (Ten thousand) |
|---|---|---|---|
| Huawei | 99887 | 22383 | 10.7 |
| Tencent | 87857 | 8294 | 6.7 |
| BYD | 33903 | 1667 | 4 |
| Digital China | 19199 | 37.6 | 0.06 |
| ZTE | 17963 | 2949 | 3.3 |

**Source:** Data from the ranking of ICT enterprises in the list of top 500 enterprises in Shenzhen for 2021.

Shenzhen is keen to develop high-level research universities and nurture clusters of world-class technology leaders to provide opportunities for SMEs. It also encourages innovation in niche industries and developing fields, forming an integrated pattern in which ICT "enterprises" drive the development of other large enterprises and SMEs.

To date, the Shenzhen government has increased its efforts to attract investment and high-quality digital economy enterprises, such as Xiaomi Information, Chinasoft International, and Jingdong, which brings vitality to the city's innovation ecosystem.

*Elements of Innovation*

Relying on a strong foundation in the ICT and software industries, Shenzhen has improved its digital infrastructure. It is the first city in the world to offer 5G independent networking. In December 2021, the number of 5G base stations reached 51,000 ranking the top in China. The company Huawei is a pioneer in 5G projects and is committed to promoting a global 5G ecosystem through collaborative R&D with multiple research institutes and universities. According to our study,

"*Huawei hopes to build a new urban infrastructure through 5G, cloud computing, IoT, big data, and artificial intelligence technologies, and join many partners to make different industry scenarios more detailed, so that enterprises, individuals, and city managers can have more access and activate new energy through data to make cities smarter and more intelligent.*" - an interviewee from Huawei.

"*Shenzhen focuses on key industrial chains and clusters, focuses on 5G, artificial intelligence, big data centers, new energy vehicles and other fields, organizes and implements key projects for technological research, and supports enterprises to solve the problems of core technologies, key components, high-end equipment, etc. that are restricted by others*." - an interviewee from the Shenzhen government.

Innovations in digital technology and the construction of an information infrastructure have led to the development of smart cities, AI, and other industries.

*Platform*

Shenzhen continuously enhances information technology innovation capabilities, realizing industrial clustering effects and developing digital industry innovation chains.

As an important digital innovation actor, Huawei works with the Shenzhen government and other companies. It has set up the Kunpeng Industry Source Innovation Center, Nanshan New Generation Information Technology Innovation Center, and Futian Soft Open & AI Innovation Center to enrich application scenarios and value co-creation. Also, the company has created a digital operation platform to resolve problems with data silos and integrated multiple business applications in the transformation of SMEs with one-stop digital service capabilities. Using cross-enterprise collaborative services, the platform can rapidly solve the difficult problems of upstream and downstream collaboration in the industrial chain.

Huawei also collaborates with various partners to build a series of ICT headquarter innovation bases, launch various SME cloud support programs, and build special industry innovation centers and joint labs.

*Digital Governance*

In terms of digital governance, Huawei and its ecosystem partners have designed the top-level architecture of a smart city for the city of Shenzhen. This has yielded real-time monitoring and intelligent early warning for urban operational situations. It also provides a wealth of solutions for government services, education, healthcare, and other areas.

In 2019, the District Smart City Intelligent Operation Centre (IOC) was created by the Shenzhen government and Huawei, which formed a three-level linked command system of city–district–street. In terms of education, Huawei and China Education Cloud jointly explored the practical application of smart classroom scenarios and created an ecosystem for sharing educational resources. In the field of medical services, the smart system Huawei Campus OptiX, has been introduced.

Shenzhen has further relaxed market access, reduced administrative licensing matters, and developed an integrated service system connecting online and offline. It actively attracts international high-level talents. By building a market-oriented trading platform, the city government has improved the data property rights trading. Several industrial parks are established to gather high-end R&D and manufacturing enterprises in the electronic information industry. Thus, policies in Shenzhen create a multi-level industrial Internet platform alongside a comprehensive digital supply chain.

**Case Two: Hangzhou City**

Located in Zhejiang Province, Hangzhou has created globally influential industrial clusters in the fields of e-commerce, cloud computing, big data, and digital security. It makes digital economy the main driving force of its development. As for innovation policies, Hangzhou issued Several Policies to Accelerate the Establishment of International Software Cities and Boost the Development of Digital Economy, highlighting out that backbone enterprises lead the process of software product implementation and technology application. The top companies in Hangzhou according to the annual turnover in 2021 are shown in Table 4.

**Table 4**
**The top companies in Hangzhou in 2021**

| Company | Annual Turnover (USD million) | R&D investment (USD million) | Technical engineer (Ten thousand) |
|---|---|---|---|
| Alibaba | 131186 | 9066 | 13.2 |
| GEELY | 15936 | 3547 | 2.3 |
| NetEase | 13741 | 2208 | 1.5 |
| Hikvision | 12767 | 1294 | 2.1 |
| Futong Group | 9439 | 378 | 0.2 |

**Source:** Data from the Top 100 Digital Economy Enterprises in Hangzhou in 2021.

*Innovator*

As a region advanced in the digital economy, Hangzhou has world-class innovative enterprises such as Alibaba, Hikvision, and H3C, alongside many SMEs. There were 10,222 national high-tech enterprises in 2021, making Hangzhou the 6$^{th}$ city to exceed 10,000 national high-tech enterprises in China.

Hangzhou not only has high-tech industrial clusters, such as e-commerce, cloud computing, and digital security, but also traditional enterprises, such as Zhongce, Wahaha, and Geely, which have built factories in the cloud, smart manufacturing models, and the "ET Industrial Brain", with more than 89,000 enterprises in the cloud. There are 14 state key laboratories, 4 provincial laboratories, 39 provincial key laboratories, 28 new provincial R&D institutions and leading enterprises forming innovation consortia, as well as a number of high-quality universities and research institutes, such as Zhejiang University and West Lake University, which provide talent training.

*Elements of Innovation*

Hangzhou has a good core industry foundation in e-commerce, the Internet of Things, ICT industry, and information software, represented by Alibaba. It has a first-mover advantage in terms of the digital economy. However, the overall manufacturing sector in Hangzhou is

relatively weak compared with Shenzhen. The promotion of new digital infrastructures such as data centers and the industrial internet has resulted in the successful applications of driverless vehicles and smart ports. This has enhanced the level of cargo trade in the Bay Area, as well as linked ports and free trade zones in the Yangtze River Delta region together.

Hangzhou is a national pilot zone the AI industry. There is a complete AI industrial chain covering core technology R&D, intelligent product manufacturing, and intelligent application from the foundation layer, the technology layer through to the application layer. As our study reveals,

"*In the future, artificial intelligence will form a very large technology industry ecosystem and become a new engine to drive industry intelligence and support the development of the digital economy*." —an interviewee from H3C.

*Platform*

Over the years, Hangzhou has leveraged close cooperation between "head enterprises" such as Alibaba, and cultivated intelligent platforms, such as Ali Cloud and City Brain. It has continuously improved the digitalization, informatization, and intelligence of traditional manufacturing enterprises, promoting the deep integration of industrial manufacturing and the Internet, and empowering users of traditional manufacturing industries. Since its inception, Zhijiang Lab has emphasized the need to "build a large ecosystem of innovation". It has cultivated real industries while being active in application development and forming an innovation ecosystem. Zhijiang Lab has also constructed emerging digital platforms, including the joint establishment of: a new generation Internet center for IPV6 together with the National Engineering Centre for Next Generation Internet; a "heaven and earth" integrated network information center with China Electronics Technology Group; and a City Brain center with Alibaba.

*Digital Governance*

With the help of Alibaba and other Internet-based enterprises, Hangzhou is the first city in China to implement the "code ride" and the electronic social security card for medical treatment, introduced the first comprehensive pilot zone for cross-border e-commerce and the first Internet court. Hangzhou has further improved economic and intellectual governance. Based on the industrial chain, fully relying on the digital means of finance, taxation and finance, taking the leading place of digital industrialization development in China as the guide, taking data as the link, deepening the integration of industries and univerities, implementing the open sharing of innovative scientific and technological resources, and enhancing the digital governance capacity of the whole city.

In 20209, the "Health Code", first introduced in Hangzhou to prevent and control the COVID-19 pandemic, was implemented in more than 200 cities across China within ten days of its launch. The system was iterated and upgraded regarded as an innovative example of Hangzhou's digital empowerment of social governance. The Hangzhou Municipal Government has also signed a cooperation agreement with Alibaba to build "the first city of digital governance in China".

**Case Three: Xuzhou City**

Xuzhou, located in Jiangsu Province, is a traditional manufacturing hub, ranking 24th among the top 100 cities in China's advanced manufacturing industry in 2021. The company XCMG has been ranked first in China's construction machinery industry for 33 consecutive years and was among the top three in the world in 2021. Additionally, Xuzhou is keen to foster digital economy clusters, such as integrated circuit, intelligent terminal, software, and IT service industries, to promote the city's innovation ecosystem. In terms of innovation policies, The Three-year Action Plan for Intelligent Transformation and Digital Transformation of Manufacturing Industry in Xuzhou supports leading backbone enterprises to build key industrial Internet platforms. The Three-year Action Plan for Industrial Digitalization in Xuzhou focuses on industrial digitalization, promoting the deep integration of digital technologies such as 5G, industrial Internet and big data with traditional industries. The top companies in Xuzhou according to the annual turnover in 2021 are shown in Table 5.

**Table 5**
**The top companies in Xuzhou in 2021**

| Company | Annual Turnover (USD million) | R&D investment (USD million) | Technical engineer (Ten thousand) |
|---|---|---|---|
| XCMG | 13226 | 698 | 0.3 |
| Xuzhou Coal MINING Group | 7447 | 82 | 0.3 |
| Xusteel Group | 2213 | 50 | 0.07 |
| Hootech | 351 | 10 | 0.02 |
| Handler | 261 | 36 | 0.04 |

**Source:** Data from the Top 50 Innovative High-tech Enterprises in Xuzhou in 2021.

*Innovator*

Based on the industrial experience accumulated by traditional large manufacturing enterprises over the years, in combination with digital transformation, the Xuzhou government encourages SMEs to "go to the cloud, to the chain and to the platform". The company XCMG acts as pioneer in forming innovation-related strategic alliances, bringing together backbone enterprises in the industrial chain, SMEs, and universities and research institutes. Among them, the output value of SMEs accounted for 19.7% of the city's total GDP in 2021. As shown in our study,

"*As a leading enterprise in the construction machinery industry, XCMG continues to drive and radiate the growth of SMEs in the related industry chain, thus enhancing the technical standard and quality level of the whole industry, realizing Made in China and constantly charging towards international competition*." - an interviewee from XCMG.

*Elements of Innovation*

With the advantages of traditional manufacturing industries, Xuzhou has built internet platforms for leading enterprises, industrial internet benchmark factories, and 5G fully connected factories. This further supports enterprises to adopt intelligent manufacturing equipment towards the digitalization of industrial systems. In 2021, 8,972 5G base stations were built, fully covering the city's 5G network. Meanwhile, big data and cloud computing have been adopted by Xuzhou's SME cloud service platform resource base. An industrial Internet platform created by the "head enterprises" also benefits SMEs, allowing them to expand service areas to the cloud, which can enhance the sharing of regional manufacturing and innovation resources.

XCMG highlights breakthroughs in key areas known as "Industrial Internet + Double Carbon", "Industrial Internet + 5G", "Industrial Internet + Park", digital twin, industrial software, and AI. It successfully improves and upgrades product functions and competitiveness. With the "5G+Industrial Internet" innovation lab jointly established with Huawei and China Unicom, and the cooperation with universities in R&D regarding common technologies for the industrial Internet, XUMG has formed a mutually supportive and win–win operation system, playing an important role in fostering Xuzhou's digital empowerment innovation ecosystem.

*Platform*

Xuzhou has expanded its service areas for SMEs, by expanding its industrial internet platforms, HanCloud and Seymour Collaborative Manufacturing. The platforms are used by ten industry sectors, with the functions of collaborative procurement, manufacturing, and distribution. It has improved the efficiency of industrial chain collaboration and the scale of supply chain integration. Data channels are open for upstream and downstream enterprises in the industry chain, which promotes cross-organizational value reinvention, eventually achieving a dynamic digital ecosystem.

The HanCloud platform has accumulated massive amounts of industrial big data, which can be applied to intelligent manufacturing, remote obstacle diagnosis, and market services. With a focus on information sharing and production cooperation, the platform can meet customized demand, improve equipment utilization, reduce financial risks through equipment location and tenant performance capability testing, and capture production and engineering construction in real time. Therefore, it contributes to the digitalization of traditional manufacturing industries. Moreover, through the collaboration with Huawei, Ali Cloud, China Unicom, an industry and technology ecosystem is formed in Xuzhou.

*Digital Governance*

Xuzhou government supports the digital transformation of manufacturing, service and agriculture, and promote the comprehensive opening of digital economy application scenarios. Also, it promotes the open sharing of data and gather leading enterprises of the digital economy in the industrial parks. For instance, XCMG as a leading enterprise, provides manufacturing

companies in Xuzhou with total solutions for industrial internet and smart manufacturing, and related consulting services.

To meet the demand for a smart park in the East Lake Biomedical Industrial Park, XCMG HanCloud used new information technologies, such as the IoT, cloud computing, and big data, to integrate the internal and external resources and services of the park, improving its overall information infrastructure.

As a new "weather vane" for economic changes such as national infrastructure construction and fixed asset investment, XCMG has created a regular data reporting mechanism comprising daily, weekly and monthly data to the city government departments. In this way, big data can inform regional macroeconomic decision-making and improve governance capabilities. Additionally, XCMG HanCloud is the first in China to match companies' human resource requirements with talent from universities. So far, XCMG HanCloud has served more than 100 institutions and cooperated with 8 institutions on research projects.

**Case Four: Weifang City**

Weifang, located in Shandong Province, is an international power city and a high-end equipment manufacturing industrial base on the Bohai Sea. It has 500 billion-level manufacturing companies in machinery, chemicals, textiles, food, and paper making. There are internationally renowned enterprises such as Weichai, GoerTek, and Haomai in Weifang. In 2021, the number of high-tech enterprises in Weifang exceeded 1,380, the highest in Shandong. Among these, Weichai Power is the leader of the engine industry and one of the top 500 enterprises in the world. In terms of the innovation policy, The Action Plan for Accelerating the Development of Digital Economy in Weifang City has strengthened digital empowerment, cultivates key industrial Internet service platforms, and builded high-level industrial Internet application demonstration projects. The top companies in Weifang according to the annual turnover in 2021 are shown in Table 6.

**Table 6**
**The top companies in Weifang in 2021**

| Company | Annual Turnover (USD million) | R&D investment (USD million) | Technical engineer (Ten thousand) |
|---|---|---|---|
| Weichai | 31918 | 1265 | 1.1 |
| GoerTek | 12253 | 674 | 1.3 |
| Chenming | 5179 | 228 | 0.19 |
| LOVOL | 2720 | 314 | 0.2 |
| Haomai | 942 | 41 | 0.25 |

**Source:** Data from the Top 50 Enterprises in Weifang in 2021.

*Innovator*

Weifang is known as a traditional manufacturing area. With its large industrial scale, the enterprise Weichai Power is surrounded by numerous SMEs, together forming a cluster. So far, the power equipment industry cluster has gathered more than 140 enterprises, with Weichai Power acting as the “chain master” for integration, connecting the upstream and downstream links in the industry chain. The company has also formed a structure of “basic parts - core parts - power assemblies - complete machines - key components”, attracting prestigious research institutes and S&T innovation platforms.

In addition to the power sector, Weifang also support other industries. Examples are Tyco from Switzerland, Knorr-Bremse from Germany, Iwatani Gas from Japan, and Shengda Technology from Korea. More than 50 enterprises have settled in the industrial parks, bringing creativity into Weifang's innovation ecosystem.

*Elements of Innovation*

The “5G + Industrial Internet” ecosystem promoted by large enterprises has boosted Weifang's data-empowered industries and enhanced the digital, networked, and intelligent development of its manufacturing industries. Traditional leading enterprises use the industrial internet platform to accelerate the development of industrial parks and to guide upstream and downstream SMEs to the cloud. This provides a hardware and software foundation for digital transformation.

Weichai Power released the Weichai Intelligent Manufacturing Strategic Plan in 2015, aiming to build a full value chain information platform. This has accelerated the digital transformation of Weifang city and promoted AI and connected vehicle businesses. The National Fuel Cell Technology Innovation Centre was also established under the leadership of Weichai Power.

*Platform*

Based on the resources from leading enterprises including Weichai Power, GoerTek, and Haomai, Weifang has built four national and 137 provincial innovation platforms. Haomai Technology’s self-developed fine chemical full continuous flow process and equipment have reached the leading position internationally. For Weifang’s photoresist provincial key laboratory, the government introduced special support policies to encourage enterprises to carry out technological innovation, to solve the problem of photoresist “neck” technology.

In addition, the “International Power City” was built by Weichai Power in cooperation with Weifang government, exploiting Weichai's brand influence and industry advantages.

*Digital Governance*

Weifang innovatively builds a "digital base" for public services and promotes the construction of an integrated big data platform. The 5G network has achieved full coverage of urban

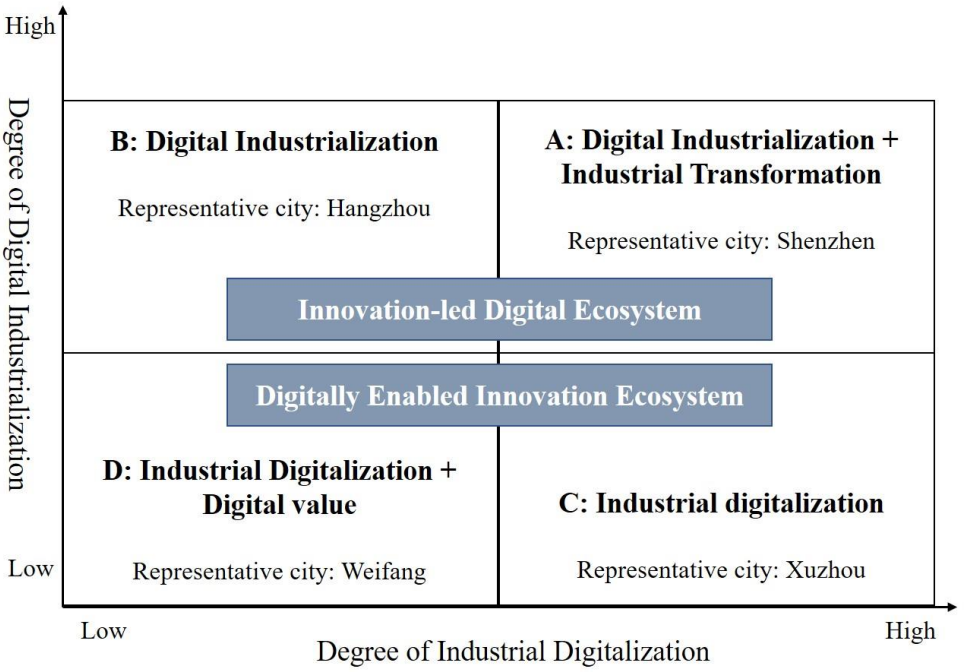
areas. There has been a transformation of smart industry with the cultivation of smart factories and digital workshops and the collaboration among industries and research institutes based on the platforms. There are systems for firefighting, traffic, housing and construction, and environmental protection. This has encouraged citizens to consider sustainable means of transport, and improved the level of intelligent governance.

Weichai Power has built a data asset sharing platform and a big data platform, which can provide cloud services to more than 1,000 industrial customers. Moreover, the cloud platform enables data collection, remote supervision, and big data fault alerting to form a full lifecycle support system. In fact, Weichai Power has established more than 6,000 service stations in China. With digital intelligent R&D systems, innovative business models, and industrial chain digitalization, Weichai has demonstrated its industry-leading role and position as a "lighthouse factory", driving the development of the regional ecosystem.

## Discussion

All four cases build on the region's advantageous industrial base as the key driver in developing innovation ecosystems, in the digital age. However, they follow different paths, which can be illustrated in Figure 2 through two dimensions. One dimension is digital industrialization, meaning digitally based innovation, collation and analysis of data to form digital products (Adner et al., 2016). The other is industrial digitalization, meaning innovation by traditional industries applying digital technology (Gupta, 2019). Accordingly, there are four quadrants: A) digital industrialization + industrial transformation, B) digital industrialization, C) industrial digitalization, and D) industrial digitalization + cultivating digital value.

**FIGURE 2**
**Four paths for cultivating regional digital innovation ecosystems.**




**Source:** Created by the authors

### Digital industrialization Drives the Development of Innovation Ecosystems

Quadrant A and Quadrant B (Figure 2) are innovation-led digital ecosystems. They refer to regions based on digital innovation. Quadrant A is represented by Shenzhen, where the digital industry ecosystem is created by large ICT enterprises. In 2020, Shenzhen boasted 21 of the top 500 ICT companies located in China, such as Huawei, Tencent, DJI, BYD, and ZTE, all of which have formed digital industry ecosystems in their respective fields. As an example, Huawei has now established digital transformation partnerships with more than 700 cities. With the help of partners, Huawei accelerates the digital transformation process of industry users globally. Meanwhile, Huawei invests heavily in technology, and unites four categories of partners, industrial alliance, business alliance, open source community and developer to promote digital transformation. Shenzhen's traditional manufacturing industry cluster also has a strong foundation, and the development of its digital ecosystem is at the forefront.

The characteristics of Quadrant A are as follows. First, ICT head enterprises play essential role by establishing a knowledge sharing platform. Based on it, alliances are formed to help enterprises update and create knowledge. Meanwhile, the collaboration of industries and universities form a consortium to transfer S&T achievements. This also integrates the innovation resources especially key technologies developed by ICT head enterprises. Second, the region demonstrates continuous innovation with new technologies and new business models constantly driving industrial innovation. Third, there are world-class enterprises, talents, advanced technologies, and other high-quality resources.

Quadrant B is represented by Hangzhou. This indicates the comprehensive transformation of service sectors, which in turn drives the digitalization process of industry. Hangzhou has advantages in terms of e-commerce infrastructure, and can lead the extensive digital transformation of the local service sectors e.g. China's first cross-border e-commerce

comprehensive pilot zone and eWTP demonstration zone. Accordingly, Hangzhou introduces policies to support employment and entrepreneurship, encouraging the market to cultivate digital platforms for new industries such as online education and online offices; innovations such as mobile payment; and the "health code". The company Alibaba leverages its technological advantages in digitalization, focusing on cutting-edge technologies such as AI, autonomous driving, chips, and quantum computing. It also assists the Hangzhou government in terms of service trading and green development. However, compared to Shenzhen, the manufacturing sector in Hangzhou is relatively weaker, indicating that Quadrant B is weaker than Quadrant A in terms of industrial digitalization.

The features of Quadrant B are as follows. First, it has clusters to attract large enterprises and talents from the backgrounds of ICT, e-commerce, AI, and financial technology. Accordingly, these enterprises advance the clusters by leveraging digital advantages, empowering traditional manufacturing industries to upgrade intelligently. Second, new technologies, products, and business models lead to the development and application of digital technology, forming a digital economy with continuous innovation. Third, these regions benefit from world-class enterprises which drive towards leading positions in the digital economy.

Based on the analysis, Proposition 1 can be made.

**Proposition 1a:** Innovation-led digital ecosystems can be cultivated in regions where ICT "head enterprises" gather and there is a strong industrial foundation. The process consists of digital industrialization led by ICT "head enterprises", in synergy with industrial digitalization empowered by digital technologies for traditional manufacturing industries.

**Proposition 1b:** In regions with advanced digital technologies and industry clusters, innovation-led digital ecosystems can be nurtured. This in turn can create regional digital industrialization and industrial digitalization systems, promoting digital value and digital governance.

### Industrial Digitalization Drives the Development of Digital Innovation Ecosystem

Quadrant C and Quadrant D (Figure 2) are digitally enabled innovation ecosystems. They are regions which enables industrial digitalization based on digital technology and integration of the constituent elements within the innovation ecosystem.

Quadrant C represented by Xuzhou are cities where the traditional manufacturing industry directs the way to create an industrial Internet-enabled digital economy. For example, XCMG's "HanCloud" platform is built on more than 70 years of industrial knowledge and 30 years of digital experience. Through the interconnection of equipment based on digital technology, the potentials of industrial big data and customer demand-oriented innovation are realized.

The main features of Quadrant C are as follows. First, the region shows a strong degree of industrial digitalization, whereas the level of digital industrialization remains relatively low for large ICT enterprises. A regional innovation ecosystem can be developed by digitalizing traditional manufacturing enterprises. Second, the leading traditional manufacturing enterprises utilize the industrial experience during digital transformation. These enterprises can build industrial Internet platforms and empower local manufacturing enterprises in digital transformation along the industry chain (Yang et al., 2021). Third, such regions can create an industrial digital brand, which attracts local enterprises "into the online cloud".

Quadrant D, as seen in Weifang, refers to traditional manufacturing regions. Through digital technology empowerment, Weifang creates a leading enterprise with Weichai Power at its center, leading to the digital transformation of numerous surrounding SMEs. For example, Weichai Power has established strategic alliances for industrial innovation, R&D platforms, and a national demonstration base for intelligent manufacturing. It has also built a global collaborative R&D platform to continuously upgrading the industry, mutually benefiting industry chain partners.

There are several characteristics of Quadrant D. First, the region has many SMEs and leading enterprises are the centers of industry chains. This strengthens the resource integration and collaboration to form a regional industrial ecosystem. The digital industrialization level is relatively low compared to areas with large ICT enterprises. Second, traditional leading enterprises utilize industrial Internet platforms to drive the adoption of business clouds by upstream and downstream SMEs. This provides a hardware and software foundation for the digital transformation of local manufacturing enterprises and fosters the regional innovation ecosystem.

Therefore, Proposition 2 can be generated.

**Proposition 2a:** In regions with a strong manufacturing foundation, a digitally empowered innovation ecosystem can be nurtured by leading enterprises from traditional manufacturing sectors. A regional digital innovation ecosystem is promoted through the digital transformation of industries in combination with digital industrialization, digital value, and digital governance.

**Proposition 2b:** A digitally empowered innovation ecosystem can be fostered in manufacturing regions with many SMEs. The process follows industrial digitalization led by "head enterprises" and together with digital value, to achieve the development of regional innovation ecosystems.

## Conclusion

This study explored approaches to cultivating regional innovation ecosystems in the digital age. Based on case studies of four cities in China, findings indicated: First, for innovation-led digital ecosystems, it is important to enhance digital innovation capabilities and maintain a first-mover advantage regarding new technologies and business models. Universities and research institutes are main suppliers of S&T innovation, which effectively promote the production, transfer and integrate knowledge (Carayannis et al, 2018). They also provide human resource for the regional innovation ecosystem (Poonjan et al, 2020). Second, to promote digitally empowered innovation ecosystems, the digital transformation of traditional industries can be essential. Third, the development of a regional innovation ecosystem led by digital industrialization and industrial digitalization needs to be accompanied by synergistic digital value and digital governance. Fourth, innovation policies play important role throughout the formation and development of innovation ecosystem. It not only maintains the stability of ecosystem, but also promotes the self-organization evolution, providing support and guarantee for the efficient and orderly activities of innovation (Poonjan et al., 2020).

We provided a theoretical analysis framework for digital innovation ecosystems and explains the characteristics of the innovator, elements of innovation, platform, and digital

governance. It is noticed that the digital economy development faces challenges. For example, digital technology acceleration can upgrade traditional industries, which may initially have a negative impact on employment. However, as digital technology becomes widely adopted, new jobs are created relating to data analysis, software and application development. The time and space constraints of employment have been further broken, promoting the global labor network. At macro level, the China-USA conflict becomes another challenge on digital technology development in China. Thus, based on the development situation, the local government in China can choose the most appropriate path to cultivate innovation ecosystem. Specifically, policies can prioritize technology R&D, development of digital technology, or drive the transformation of traditional manufacturing industry, in accordance with the degrees of digital industrialization and industrial digitalization of the region.

As for the future research, the propositions in this paper needs validation. Also, there is a need to explore the dynamic evolutionary process at macro and micro levels (Yun, 2015; Yun et al., 2016). Comparative studies in regions outside China can also advance the theory of innovation ecosystem in the content of digital transformation.

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## REFERENCES

Adner, R. (2016). Ecosystem as structure: an actionable construct for strategy. *Journal of Management*, 43(1), 39-58.

Ardolino M, Rapaccini M, & Saccani N. (2018). The role of digital technologies for the service transformation of industrial companies. *International Journal of Production Research*, 56(6): 2116-2132.

Beltagui, A., Rosli, A., Candi, M., Bell, M., Martin, B., & Steinmueller, W. E. (2020). Exaptation in a digital innovation ecosystem: The disruptive impacts of 3D printing. *Research Policy*, 49, 1.

Bharadwaj, A., El Sawy, O. A., Pavlo, P. A. & Venkatraman, N. (2013). Digital Business Strategy：Toward a Next Generation of Insights. *MIS Quarterly*, 37(2), 471-482.

Bittencourt, B. A., Santos, D. A. G. D., & Mignoni, J. (2021). Resource orchestration in innovation ecosystems: a comparative study between innovation ecosystems at different stages of development. *International Journal of Innovation*, 9(1):108-130.

Boudreau, K., & Jeppesen, L.B. (2019). Protecting their Digital Assets: The use of formal & informal appropriability strategies by App developers. *Research Policy*, 8, 1-13.

Carayannis, E.G., Grigoroudis, E., & Campbell, D.F. (2018). The Ecosystem as Helix: an Exploratory Theory-Building Study of Regional Co-Opetitive Entrepreneurial Ecosystems as Quadruple/Quintuple Helix Innovation Models. *R&D Management*, 48(1) :148-162.

Chae, B.K. (2019). A General framework for studying the evolution of the digital innovation ecosystem: The case of big data. *International Journal of Information Management*, 45, 83-94.

Chen, K. (2020). Accelerating the digital transformation of innovation − driven development. Outlook Weekly, 52: 24-26 .

Constantinides, P., Henfridsson, O., & Parker, G.G. (2018). Platforms and infrastructures in the digital age. *Information Systems Research*, 29(2): 381-400.

Frank, A.G., Mendes, G., Ayala, N. F., & Ghezzi, A. (2019). Servitization and industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. *Technological Forecasting and Social Change*, 141, 341-351 .

Gawer, A. (2014). Bridging Differing Perspectives on Technological Platforms： Toward an Integrative Framework. *Research Policy*, 43(7): 1239-1249.

Goldfarb, A., & Tucker, C. (2019). Digital economics. *Journal of Economic Literature*, 57(1): 3-43.

Gomes, L.A., Facin, A.L., & Salerno, M.S. (2018). Unpacking the innovation ecosystem construct: Evolution, gaps, and trends. *Technological Forecasting and Social Change*, 136, 30-48 .

Gorwa, R. (2019). What is Platform Governance? *Information, Communication & Society*, 22(6):854-871.

Gupta, R., Mejia, C. & Kajikawa, Y. (2019). Business, innovation and digital ecosystems landscape survey and knowledge cross sharing. *Technological Forecasting and Social Change*, 147, 100-109.

Helfat, C.E., & Raubitschek, R. (2018). Dynamic and integrative capabilities for profiting from innovation in digital platform-based ecosystems. *Research Policy*, 47, 1391-1399.

Huang, X., Ma, L., Li, R., & Liu, Z. (2020). Determinants of innovation ecosystem in underdeveloped areas: Take Nanning High-Tech Zone in western China as an example. *Journal of Open Innovation: Technology, Market, and Complexity*, 6(4), 135.

Izaskun A.M, Naiara P.G, & Rosa M.R.B. (2020). Knowledge sharing and transfer in an open innovation context: Mapping scientific evolution. *Journal of Open Innovation: Technology, Market, and Complexity*, 6(4),1-23.

Jacobides, M. G., Cennamo, C., & Gawer, A. (2018). Towards a theory of ecosystems. *Strategic Management Journal*, 39, 2255-2276.

Kim, Y, & Kim, B. (2020). Selection attributes of innovative digital platform-based subscription services: A case of South Korea. *Journal of Open Innovation: Technology, Market, and Complexity*, 6(3):70-84.

Krishna, V.V., & Sha, S.P. (2015). Building science community by attracting global talents: the case of Singapore Biopolis. *Science, Technology and Society*, 20(3):389-413.

Krishna, V.V. (2019). Universities in the national innovation systems: Emerging innovation landscapes in Asia-Pacific. *Journal of Open Innovation: Technology, Market, and Complexity*, 5(3): 43.

Lee, M., Carayannis Carayannis, J.J., Pyka, A., Won, D., Kodama, F., Schiuma, G., Park, S., Jeon, J., Park, K., Jung, K., Yan, M.-R., Lee, S., Zhao, X. (2018). How to respond to the fourth Industrial Revolution, or the second Information Technology Revolution? Dynamic new combinations between technology, market, and society through open Innovation. *Journal of Open Innovation: Technology, Market, and Complexity*, 4(3): 21.

Li, T., Ma, L., Liu, Z., & Liang, K. (2020). Economic granularity interval in decision tree algorithm standardization from an open innovation perspective: Towards a platform for sustainable matching. *Journal of Open Innovation: Technology, Market, and Complexity*, 6(4), 149.

Liang, K., Ma, L., Liu, Z., & Li, T. (2022). Structuring and operating patent intermediary as platform ecosystem: Case studies of patent operation platforms (POPs) in China. *Science, Technology and*

*Society*, 27(2), 191-212.

Liu, Y., Dong, J., & Jiang, W. (2020). Digital innovation management: Theoretical framework and future research. *Management World*, 36 (7): 198-217, 219.

Ma, L., Liu, Z., Huang, X., & Li, T. (2019). The impact of local government policy on innovation ecosystem in knowledge resource scarce region: Case study of Changzhou, China. *Science, Technology and Society*, 26(1), 1-24.

Nadkarni, S., & Reinhard P. (2020). Digital transformation: a review, synthesis and opportunities for future research. *Management Review Quarterly*, 1-109.

Nambisan, S., Lyytinen, K., Majchrzak, A., & Song, M. (2017). Digital innovation management: reinventing innovation management research in a digital world. *MIS Quarterly*, 41(1): 223-238.

Nambisan, S., Wright, M., & Feldman, M. (2019). The digital transformation of innovation and entrepreneurship: progress, challenges and key themes. *Research Policy*, 48(8), 103773.

Poonjan, A., Tanner, A.N., & Andersen, P.D. (2020). How regional factors influence the performance of science and technology parks: A comparative analysis of regional science parks in Thailand. *Asian Journal of Technology Innovation*,355, 1-23.

Radicic, D., Pugh, G., & Douglas, D. (2020). Promoting cooperation in innovation ecosystems: evidence from european traditional manufacturing SMEs. *Small Business Economics*, 54(1): 257-283.

Ramezani, J., & Camarinha-Matos, L. (2020). Approaches for resilience and antifragility in collaborative business ecosystems. *Technological Forecasting and Social Change*, 151, 119846

Reinartz. (2017). Digital transformation and value Creation: Sea change ahead. *GFK Marketing Intelligence Review*, 9(1): 10-17.

Saberi, S., Kouhizadeh, M., & Sarkis, J. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*, 57(7): 2117-2135.

Schmeiss, J., Hoelzle, K., & Tech, R. P. (2019). Designing governance mechanisms in platform ecosystems：Addressing the paradox of openness through blockchain technology. *California Management Review*, 62(1):121-143.

Setzke, D.S., Riasanow, T., Bhm, M., & Krcmar, H. (2021). Pathways to digital service innovation: the role of digital transformation strategies in established organizations. *Information Systems Frontiers*, 3, 1-21.

Täuscher, K. & Laudien, S.M. (2018) Understanding Platform Business Models:A Mixed Methods Study of Marketplaces. *European Management Journal*, 36(3). 319-329.

Teece, D.J. (2018). Profiting from innovation in the digital economy: enabling technologies, standards, and licensing models in the wireless world. *Research Policy*, 47,1367-1387.

Verhoef, P.C., Broekhuizen, T, & Bart, Y. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, 122, 889-901.

Xu, H., Zhang, Y., & Cao, Y. (2020). Digital economy, technology spillover and dynamic coopetition policy. *Management World*, 36(11): 63-84.

Yang, W., Liu, J., & Wu J. (2020). The impact of population -flow configuration on focal firm's performance - Empirical research on digital innovation ecosystems in artificial intelligence industry. *Studies in Science of Science*, 38(11): 2077-2086.

Yoo, Y., Henfridsson, O., & Lyytinen, K. (2010). Research commentary - the new organizing logic of digital innovation: An agenda for information systems research. *Information Systems Research*, 21(4): 724-735.

Yun, J.J, Won, D., Park, K. (2016). Dynamics from open innovation to evolutionary change. *Journal of Open Innovation: Technology, Market, and Complexity*, 2(2): 1-22.

Yun, J.J. (2015). How do we conquer the growth limits of capitalism? Schumpeterian dynamics of open

innovation. *Journal of Open Innovation: Technology, Market, and Complexity*, 1(2): 1-20.
Yun, J.J, Jeong, E., Yang, J. (2015). Open innovation of knowledge cities. *Journal of Open Innovation: Technology, Market, and Complexity*, 1(2): 1-20.
Yun, J.J, Yang, J., & Park, K. (2016). Open innovation to business model: new perspective to connect between technology and market. *Science, Technology, and Society*, 21(3), 324-348.
Yun, J.J., Zhao, X., Ma, L., Xu, Z., & Liu, Z. (2022). Open innovation and multi-homing of delivery platforms: Comparative study of Cardiff, Daegu, and Nanjing. *European Planning Studies*, DOI: 10.1080/09654313.2022.2069463.
Zhang, C., Chen, K. & Ping, M. (2021). The digital innovation ecosystems: Theory building and a research agenda. *Science Research Management*, 42(3): 1-11.
Zhao, A., Ma, X., & Tian, F. (2016). The development level of China's industrial land market and its influencing factors based on the perspective of resource value manifestation. *Resource Science*, 2.