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The Impact of Local Government Policy on Innovation Ecosystem in Knowledge Resource Scare Region: Case Study of Changzhou, China

[AQ1]

LEI MA, ZHENG LIU, XIAOJING HUANG and TAO LI

With business today relying increasingly more on collaboration, new product development is also on a network base. The concept of innovation ecosystem is built upon knowledge creating and sharing across companies, knowledge institutions, policy regimes, business enterprises and industry boundaries. China as the largest emerging market has witnessed innovation with interaction among government, university, industry and research. Though government plays an important role in promoting innovation, not many studies have covered the detailed dynamic process and impact of policy on forming innovation ecosystem, especially in places where initial knowledge resources such as universities and research institutes are limited. Therefore, our article aims to fill in this research gap. Through document review and case study on Changzhou region of China,[1] we map out the local government policy concerns and changes during each stage of innovation ecosystem formation, development and expansion from 2001 to 2015. The interaction mechanism among government, university, industry and research is summarised with a proposed framework to highlight the key policy making areas. Further research areas are recommended with implication and conclusion.

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Introduction

Business and innovation processes nowadays are increasingly relying on collaboration and network. Many multinational enterprises (MNEs) build innovation networks by establishing R&D centres overseas. Companies can absorb knowledge from a dispersed knowledge hub (Krishna, Patra, & Bhattacharya, 2012; Patra & Krishna, 2015). Innovation strategy has expanded with the trend of globalisation. On a regional level, with a city changing from an industry focused towards a creative one, knowledge will spread even more (Yun, Jeong, & Yang, 2015). Through open innovation and coordination, companies attract the participation of external contributors to create knowledge collectively (Chesbrough & Appleyard, 2007). New product development depends on a network of companies, suppliers, research institutes, competitors and customers. This happens not only to leading Western mega firms such as Intel, Google and Apple, but also to small and medium enterprises (SMEs) in emerging countries including India and China. Studies suggest that industry-academia linkage is still weak in India, though the government research laboratories are strong, and as a result, open innovation can be an effective way of generating new knowledge (Krishna et al., 2012; Patra & Krishna, 2015). Traditionally, China is known for its strong manufacturing capability. With the Chinese central government promoting original design and knowledge creation, firms now seek for upgrading towards high value-added activities. Large firms can collaborate extensively with supply chain partners on product development. Meanwhile SMEs also make efforts together, learning and sharing resources with research institutions, gradually forming a network based innovation ecosystem. Innovation ecosystem consists of economic agents, economic relations as well as the non-economic parts such as technology, institutions, sociological interactions and culture (Mercan & Goktas, 2011). It shows the feature of inter-firm collaboration, resource sharing and co-evolution across regions and sometimes across industry. The system emphasises the connection among industry, university and government, known as the triple helix (Etzkowitz & Leydesdorff, 1995). The model can be expanded towards the interaction among industry, university, research institutions and users, called as the Quadruple Helix (Carayannis & Campbell, 2009). The concept of smart city also appears as it combines regional innovation, thinking, planning and technological advancement (Lara, Moreira Da Costa, Furlani, & Yigitcanlar, 2016).

In China, there is a trend of a typical innovation ecosystem consisting of companies, universities and research institutions in a certain region or cluster, with service infrastructure supported by the local government (Ran & Liu, 2014). So far, research has covered technology and production innovation from micro-level perspectives of firms, in particular in the high-tech industry, such as mobile computing. Investigations can be seen in terms of resource, value creation, core companies and geographic clusters, key themes including innovation process, innovation activities and effects of innovation to market and economic factors (Witt, 2016). While most studies are based on Western leading MNEs, observations from SMEs and developing countries are growing rapidly (Patra & Krishna, 2015). For example, Park and Lee (2015) aim to verify the relationship between Korean government policy literacy and innovation initiatives. Kim, Kim, Suh, and Zheng (2016) highlight government supporting system in R&D activities of Korean firms. It is suggested that non-technological elements such as strategy, culture and institution play vital roles in building up the competence of innovation ecosystem (Xu et al., 2007). However, the impact of policy on nurturing ecosystem, particularly in regions previously lacking of innovation capability is unknown. Thus, the main objective of this article is to find out the linkage between local government policy and innovation starting from limited knowledge resource towards a mature ecosystem.

The key research question of this article is 'what is the role of local government policy on the development of innovation ecosystem in knowledge resource scare region'. With emphasis on interaction mechanism, an in-depth case study on Changzhou, a recently fast-growing region in China based on innovation, is conducted. The study specifically aims to identify:

- Key activities of how innovation ecosystem is formed, developed and expanded from limited knowledge resource.
- Role of local government policy at each stage of innovation ecosystem process.
- Interaction mechanism among different players in the innovation ecosystem.

Changzhou is a city located in Southern Jiangsu Province (this area usually includes cities of Nanjing, Zhenjiang, Changzhou, Wuxi and Suzhou), in the middle of Nanjing and Shanghai, with a history of more than 3,200 years. Changzhou has a total area of 4,373 square kilometers and population of 4.7 million (http://www.changzhou.gov.cn/). In 2016, the registered population of the Southern Jiangsu was 24.7407 million with GDP 4479.583 billion RMB, of which Changzhou's GDP was 577.386 billion RMB (Jiangsu Province Bureau of Statistics, 2017).

Literature Review

The topic of the interaction between policy and innovation can be explored from technology and innovation policies, and innovation ecosystem. Traditionally, innovation mostly takes place closely within companies due to ownership and control. Schumpeter (1934) is regarded as the first scholar who demonstrated that connection between technology and market can lead to society innovation. The concept of open innovation emerges as firms link with each other, developing new product and service in a flexible open way (Chesbrough, 2003; Chesbrough & Appleyard, 2007). Open innovation are studied mainly from four theories (Yun, Won, & Park, 2016): resource and knowledge based theories as a way to exploit resources (Das & Teng, 2000) and build capability through multiple channels [AQ2]

(West & Gallagher, 2006); transaction cost theory to reduce costs through vertical disintegration (Jacobides & Winter, 2005); historical friendly model; and dynamic capability theories to cope with rapid technological change (Teece, Pisano, & Shuen, 1997).

Open innovation provides alternatives for companies to create knowledge through sharing, whereas the concept of innovation ecosystem refers to regional level innovation with multiple players. According to Moore (1993), business ecosystem combines the feature of strategic alliance, open innovation, supply chain with diverse products and broader collaboration range. It is a dynamic process starting from existing collaboration network to expansion, convergence and renewal (Moore, 1993). Iansiti and Levien (2004) suggest that resource sharing with external partners can result in innovation. Adner and Kapoor (2010) emphasise the co-innovation among supply chain partners, and propose the concept of innovation ecosystem. The term of innovation ecosystem is then defined as 'the complex relationships that are formed between actors or entities whose functional goal is to enable technology development and innovation (Jackson, 2011)'. Though business ecosystem and innovation ecosystem both require platform and network, it is argued that business ecosystem mainly means value capture, whereas innovation ecosystem focuses on value creation (Gomes, Facin, Salerno, & Ikenami, 2016). Innovation ecosystem is mentioned in contexts such has open innovation, regional and national innovation ecosystem, digital innovation ecosystem, city-based innovation ecosystems, high-tech SMEs-centred ecosystem and university-based ecosystem (Oh, Philips, Park, & Lee, 2016). According to a recent literature review, research streams in innovation ecosystem include industry platform design and management, strategy and business model of innovation ecosystem, risk management, partner management, lifecycle of innovation ecosystem and new venture creation (Gomes et al., 2016).

Cluster and regional innovation studies also reveal the interaction among government-support, market-oriented and university-driven (Hu, Huang, & Du, 2016). The case of Silicon Valley provides good practice of collaboration between research institutions and industry. Meanwhile, government polices give support for innovation enterprises, market and logistics (Kenny, 2000). Empirical study on Taiwan Hsinchu Science Park demonstrates that external knowledge including new and extended industrial clusters play important role. Within the regional innovation ecosystem, the capital, manpower and technology flows are conducted respectively by large companies, top universities and research institutions in the local area (Hu, 2011). Investigation into four Korean cities suggests that the creating of new knowledge is influenced by large companies, however, SMEs can generate knowledge and patent through open innovation (Yun et al., 2015). By analysing the urban form, connectivity and knowledge-intensive production in Helsinki and its surrounding area, Inkinen (2015) discovers that: (a) locations and regional contexts influence pathways of regional innovation; (b) regional innovation is connected with universities; and (c) companies and mediating organisations support service of innovative location. On a national level, the socio-economic conditions together with the scientific and technological capability indicate national innovation system (NIS). The concept of NIS can explain the rapid growth of Japanese economy during the 1980s (Lee, Moon, Sung, & Shin, 2007), as specific institutions such as companies, research centres and universities interact to social institutes, meaning values, norms and laws (Jeon, Kim, & Koh, 2015). To find out the governance of innovation ecosystem, Chen, Gao, Liu, and Ma (2016) proposed four mechanisms: technology standard (the innovation system is formed by core companies or technology), outsourcing innovation along the supply chain, cluster and platform based ecosystem. To further capture the dynamic feature of innovation ecosystem in China, researchers have epxlored ecosystem growth mechanism (Lyu, Lan, & Han, 2015), its coupling relations with technology population (Zhang, 2015), multi-level environmental factors (Xu & Li, 2014) and innovation efficiency (Liu & Chen, 2015). A recent case study of a Chinese motorcycle company suggests that the development process of innovation ecosystem involves three phases, namely capability gap articulation, development and initialisation (Qian et al., 2016). Research gives importance to market forces of innovation ecosystem, relative to government or NGO's push (Oh et al., 2016). It is found that network-based strategy of growth is suitable for companies in planned economies in transition such as China (Peng & Heath, 1996).

Another research stream, overlapping with innovation ecosystem is the triple helix theory, which highlights the interaction among university, industry and government for knowledge creation and sharing. Triple helix emphasises the non-linear connection, where industry acts as the source of production, government provides regulations, stability and rules of play and universities are suppliers of new knowledge and technology (Etzkowitz, 1993; Etzkowitz & Leydesdorff, 1995, 2000). [AQ3] The literature of triple helix can be summarised from two perspectives (Ranga & Etzkowitz, 2013): (a) institutional perspective, which analyses the configurations in the positioning of the university, industry and government institutional spheres; (b) evolutionary perspective, emphasising the dynamics of innovation and proposing the central concept of entrepreneurial university. Recent studies also focus on the concept of triple helix systems of innovation (Ranga & Etzkowitz, 2013), which differentiates R&D and non-R&D innovators, single-sphere and multi-sphere institutions and individual and institutional innovators. To foster technology development infrastructure, government can use both mission-orientation and diffusion-orientation policy mechanism. In particular mission-orientation policy can develop technology leadership and create standards, whereas diffusion-orientation policy incrementally builds service capability by encouraging wider participants (Yu, Yue, & Ping, 2012). Government can use direct and indirect mechanisms, including policy, information, technology and service support to encourage interaction between universities and industries (Hu et al., 2016). By comparing Jiangsu Province (China) innovation policies of scientific talents, patent and R&D, Ma, Liu, Jiang, Yu, and Gan (2016) analyse the characteristics of innovation policy tools mix from innovation 1.0 to 3.0.

Current literature has provided adequate conceptual framework of innovation within and between organisations, covering clusters and regional levels. However, not many studies emphasise the innovation process of late comers in emerging economies, in particular regions in shortage of innovation resources. For example, in China, though open innovation can be effective approach for companies to share knowledge, without existing collaboration network and external support, it is difficult to achieve high performance. The studies of innovation ecosystem highlight network expansion and renewal based on existing partnership. Triple helix and policy studies demonstrate non-linear interaction, however, the details of how local government's role should change along with different stages of the innovation ecosystem are not clear. Thus this research aims to contribute to the theory of innovation ecosystem from this perspective.

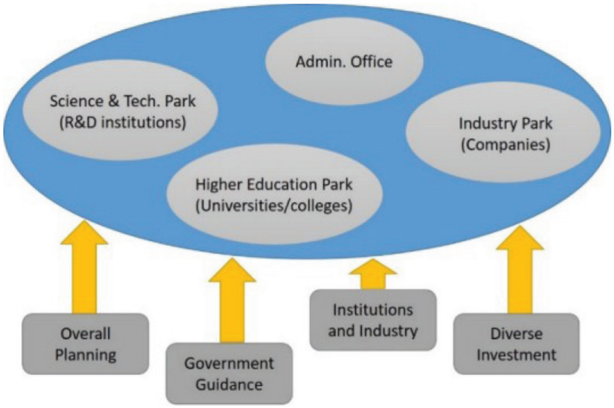
Research Methodology

Our research aims to find out the role of local government policy on the development of innovation ecosystem in knowledge resource scare region. The nature of this topic requires for a theory-building approach with qualitative methodology, which can provide a deep understanding on significant issues which have not been explored (Yin, 2003). As innovation ecosystem is a concept dealing with multiple actors in a regional context, we select Changzhou city as the in-depth single case study. Changzhou is located in the southern part of Jiangsu Province, China. In 2016, its total GDP was 577.386 billion RMB, GDP per capita reaching 18,500 RMB. It has a permanent population of 4.7 million, of which 3.387 million are urban (urbanisation rate 71.8%). Currently there are 80,000 private enterprises, among which 13 enterprises have entered 500 strongest private enterprises in China (with more than 10 billion RMB annual income). In 2016, there were 1,231 high-tech enterprises in the city, with 15,349 patent applications and 2,865 patent authorisations. Changzhou ranks among the top 30 cities national wide, according to its comprehensive competitiveness (Changzhou Bureau of Statistics, 2017).

There are several reasons to choose Changzhou city as the in-depth case study: (a) Changzhou, though located in the commercialised Yangtze River Delta of China, had very few universities before 2000, regarded as knowledge resource region. (b) Changzhou innovation ecosystem, starting from almost nothing has clearly experienced different phases (Ma, 2017). During 2001 and 2005, privately owned enterprises in Changzhou started to approach the local government, seeking help on science and technology resources. From 2006 to 2010, with series of polices issued, the 'Changzhou model' (Figure 1) was developed, combining science education and industry based on public service. With innovation ecosystem gradually mature, during 2011 and 2015, the Changzhou model was continuously expanded through internationalisation, aggregation of global resources, and participation of financial capital intermediaries. The dynamic process of Changzhou innovation ecosystem along with time provides opportunities of in-depth studies into each stage. Furthermore, its clear structure enables detailed exploration into the ecosystem, from government admin offices, universities and colleges, R&D institution, major firm and business enterprise and service provider perspectives. Table 1 is an illustration of Changzhou innovation ecosystem structure. (c) Local

Figure 1
Changzhou Innovation Ecosystem (Changzhou Model)

[AQ4]



Source: Compiled from Zou (2015)**.**

Table 1
Examples of Actors in Changzhou Innovation Ecosystem

[AQ5]

Type of Actors	*Examples*
Government admin offices	Changzhou Science and Technology Bureau, Changzhou Science Education City Administration Committee, Changzhou Intellectual Property Office
Science and technology parks	Changzhou Science and Technology Park, The National University Science Park of Changzhou R&D Park, Hua Luogeng Science Park, Hengsheng Science Park, China–Israel Innovation Park, Smart City Science Park, National Culture Science and Technology Integration Base, High-end Equipment Science and Technology Industrial Park, New Material Science and Technology Industrial Park, Photovoltaic Science and Technology Industrial Park, Biological Science and Technology Industrial Park
Industry parks	Changzhou West Taihu Science and Technology Industrial Park, Rail Transportation Science and Technology Industrial Park, Green building Industrial Cluster, Jiangsu Zhongguancun Science and Technology Industrial Park, Tianning Science and Technology Industrial Park, Zhonglou Science and Technology Industrial Park, Intelligent Equipment science and Technology Industrial Park, Energy and Environmental Technology Industrial Park, Electronic Information Science and Technology Industrial Park
Higher education parks	Changzhou Science and Education City
Research/R&D institutions	Changzhou Advanced Manufacturing Technology R&D and Industrialisation Centre, Changzhou Semiconductor Lighting Application Technology Institute, Institute of Intelligent Science & Technology Application, CAS (China Academy of Sciences) Robots and Intelligent Equipment, CAS Research Institute of Advanced Manufacturing, CAS Research Institute of Optoelectronic Technology, Research Institute of Nanjing University in Changzhou (Target Pharma), Research Institute of Beijing University of Chemical Technology in Changzhou (Green Chemical Materials)

(Table 1 continued)

(Table 1 continued)

Type of Actors	*Examples*
Universities and colleges	Changzhou University Petrochemical Technology (renamed as Changzhou University in 2010), Changzhou Technician College (renamed as Jiangsu University of Technology in 2012), Changzhou Institute of Technology, Hohai University (Changzhou Campus), Changzhou College of Information Technology, Changzhou Vocational Institute of Textile and Garment, Changzhou Vocational Institute of Engineering, Changzhou Vocational Institute of Light Industry, Changzhou Institute of Mechatronic Technology
Major firms and business enterprises	Zhong Jian Science and Technology Development Co., Ltd, Zenith Steel Group, Trina Solar, Hengli Group, Changfa Group, Changlin Co., Ltd, Huapeng Transformer, Changchai Co., Ltd, Changzhou Wujin Zhong Rui Electronics Co., Ltd, Changzhou Long Chun Tian pure Environmental Protection Technology Co., Ltd, Jiangsu Kang Shun medical purification Engineering Co., Ltd, Jado New Energy, Shangshang Cable Group
Service providers	Changzhou Intellectual Property Office, Jiangsu Bai Teng Technology Co., Ltd, China (Changzhou) Intellectual Property Rights Assistance Center, Changzhou Technical Property Right Trading Center Co., Ltd, Changzhou Guang Zheng Intellectual Property Agency Co., Ltd, 'Everyday 518' on-line Technology Service Platform
Incubators	Zhonglou District Innovation Service Center, Creator Coffee, Five Stars Creator, TusStar Foundation, Changzhou Buyun Science and Technology Pioneer Park, Erwei International Artificial Intelligence Incubator

Source:

government plays an essential role in Changzhou innovation ecosystem, by issuing different policies at each stage. Analysis can be made to link the impact of policies to universities, research institutions and industry, and thus to the whole ecosystem on the regional level. (d) Since success, Changzhou innovation model has attracted nation-wide attention. It demonstrates good practice for regions which aim to upgrade towards high value-added performance by forming innovation ecosystem from limited knowledge resources. Polices derived from Changzhou case study can be potentially implemented in other regions. (e) Data access to Changzhou innovation ecosystem, including government reports, documents and interview to government admin office, university and companies is available for this research.

Our data collection method includes document review and interviews. To capture series of local policies and events related to innovation from 2001 to 2015, archival data was collected from Changzhou and Jiangsu province government statistics yearbooks, industry reports (provided by Changzhou Science and Technology Bureau) and press releases of interviewing Changzhou government officials. Both public archival data and company/government archival records were used. Meanwhile, semi-structured interviews were conducted with field visits to obtain primary case data.

To understand details of government policies, we interviewed two officials from Changzhou Science and Technology Bureau, and Changzhou Science and Education City Administration Committee. Questions were focused on the background and prioritised concerns of issuing each policy, institutional and macro-environmental factors, government interaction activities with the ecosystem and strategic decisions of Changzhou innovation ecosystem. In addition, our selected universities and research institutes in Changzhou city for interview were Changzhou University, Changzhou Vocational Institute of Engineering, Changzhou Engineering School, Changzhou Advanced Manufacturing Technology R&D and Industrialization Centre (jointed founded by Changzhou government and China Academy of Sciences), Research Institute of Nanjing University in Changzhou (founded by Nanjing University) and Changzhou Semiconductor Lighting Application Technology Institute. To capture policy's impact on company innovation strategy, we also interviewed four technology and innovation focused companies in Changzhou, which were Changfa Group (agricultural machinery and refrigeration equipment industry), Changlin Co., Ltd (manufacturer and distributor of construction machinery and construction equipment industry), Hengli Group (manufacturer of hydraulic components and systems) and Huapeng Transformer (manufacturer of power transformer). We held at least two hour face-to-face interview or 30 minutes telephone interview when a field visit was unavailable. After the interview, we mapped out the innovation stages and network of university-industry-research-government connection, summarising case reports with confirmation from the interviewees. Sample questions during our semi-structured interviews were designed, with open discussion on innovation ecosystems asked during the conversation (Appendix Table A1).

Findings and Discussion

In this in-depth case study, we have collected data from government, university, research and industry. By integrating data together, we have developed a staged model of Changzhou innovation ecosystem with key events and government policies; a framework of innovation ecosystem; and the interaction mechanism among different players in the ecosystem, in particular the relationship among government, university, industry and research. From our investigation, Changzhou innovation ecosystem has experienced three main stages.

Stage One

Stage one (2001–2005) was the early formation stage. Changzhou city is located in Jiangsu Province in the Yangtze River Delta, a most active area in China's economy. There are five major cities in the Southern Jiangsu, Suzhou, Wuxi, Changzhou, Zhenjiang and Nanjing. With technology advancement and international manufacturing transfer, both Jiangsu government and academic scholars proposed the idea of constructing this region (Yu, Ding, & Wang, 2010). The official statement was formalised later on[2] by the National Development and Reform Commission. From 2001 to 2005, Changzhou government aimed to strengthen the scientific and technological regulations and policy system, introducing policies including 'Changzhou manufacturing information engineering pilot implementation', 'promoting the progress of science and technology', 'reward system on science and technology', and regulations to 'speed up international scientific and technological collaboration, the development of private science and technology enterprise, intermediaries and industrial clusters' (Changzhou Government, 2006). Changzhou was a representative of Southern Jiangsu economy, with private enterprises accounting for 38 per cent of GDP in 2005, compared to 9.6 per cent in 1999 (Jiangsu Province Bureau of Statistics, 2006). However, lacking of knowledge and talents was obstacle to the regional development. Before 2000, Changzhou had only four universities and colleges, namely Jiangsu Institute of Petrochemical Technology (renamed as Changzhou University in 2010), Changzhou Technician College (renamed as Jiangsu University of Technology in 2012), Changzhou Institute of Technology and Hohai University (Changzhou Campus). Family-owned companies had very little R&D capability and capital. Thus the innovation ability was limited (Changzhou Government, 2006; Changzhou Municipal Archives Bureau, 2011).

In view of this, Changzhou Science and Technology Bureau decided to construct a regional innovation system, by cultivating high-tech companies and research institutes, and establishing

> 78 enterprise technology centres, including 3 national level, 15 provincial and 60 municipal level, 27 engineering research centres, including 1 national, 9 provincial and 17 municipal, 3 post-doctoral technical innovation centres, and 19 scientific research institutes. These institutions not only made significant achievements in research and development, but also set up an effective operating mechanism. The infrastructure played an important role in the development of high-tech industry and the construction of regional innovation system. (Changzhou Government, 2006)

To enrich knowledge resource, the government launched large-scale seminars, inviting Tsinghua University,[3] Peking University,[4] Southeast University,[5] Xi'an Jiao Tong University,[6] Zhejiang University,[7] and China Academy of Sciences[8] for education and research exchange. This helped companies to solve problems concerning science and technology, and created an innovative culture. With resource sharing, education programmes, conferences and forums were launched by universities in and outside Changzhou. Companies participated for collective learning, building research centres together with universities. A special admin office, the Technology Management Office, was formed by Science and Technology Bureau to coordinate activities. At this stage, service and IP protection were incomplete yet. The government mainly focused on the nurturing SMEs and research centres. There were more than 400 innovation forums, resulting in 2000 collaboration projects, and 31.3 billion RMB technology related trading (data source: interview to Changzhou Science and Technology Bureau).

It is seen that before 2000, the knowledge resource in Changzhou was limited, with few number of universities, shortage of research institutions and leading large firms. It was the Changzhou Science and Technology Bureau, the local government, who played essential role to promote innovation from almost nothing. It emphasised resource creation, in particular university and research resources, through inviting external experts, forming education forums and funding research centres. Then it encouraged local SMEs to interact with universities and research centres. To achieve this, the government created enterprise technology centres, engineering technology centres, postdoctoral workstations and SME technology centres. The establishing of science and technology forum, the rewarding system and the policy of 'Changzhou manufacturing information engineering pilot implementation' largely encouraged knowledge creation and sharing between industry, research and university. While ideas, knowledge, technology, inter-organisational collaboration were prioritised, training, testing, quality control and IP protection were still incomplete. Therefore, this stage was regarded as the early formation of innovation ecosystem. The key actors were government, universities, research centres and industry, of which government is the driver.

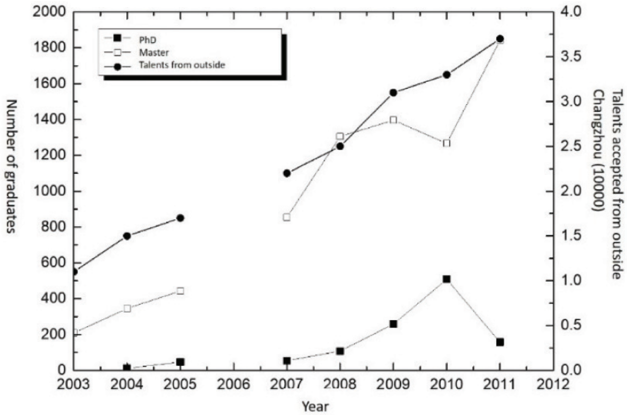
Stage Two

At stage two (2006–2010), while university, government, industry and research remained as actors, agents such as service providers and financial institutes emerged. Interaction within the innovation ecosystem was more frequent, diversified with less interference from the government whose main role was to establish platform to facilitate knowledge sharing, training programmes and quality control system. This stage can be regarded as the improvement of Changzhou innovation ecosystem.

At the starting point, the knowledge resource and innovation environment were still weak with insufficient achievements. Facing the problems, the Changzhou Science and Technology Bureau decided to form a distinctive Changzhou model by combining government policy, industry, research centres and university resources together. As seen from Figure 1, Changzhou model highly integrated the resources among different actors inside the ecosystem. The government is responsible for overall planning, providing guidance and platforms for knowledge sharing. To further encourage regional learning and training, the government constructed Changzhou Science Education City, founding five higher occupation education schools,[9] together with the previous four higher education institutions, training 20,000 technical personnel annually. During 2006 and 2010, 30 per cent local graduates stayed in Changzhou. In addition, more than 2000 overseas experts were invited to lead key R&D projects, as part of the government 'thousand overseas talents' and 'golden phoenix' projects, which provided employment opportunities and housing allowance. In addition, Changzhou government highlighted five mechanisms, namely selection training, intermediary service, long-term cooperation, trust and benefit sharing, as guidance for university and industry collaboration (Changzhou Bureau of Statistics, 2006–2010). Figure 2 shows the number of graduates (Masters and PhDs) and talents in Changzhou from 2003 to 2012.

With new policies such as '40 implementing advices and 27 specific operational rules to encourage innovation', 'joint meeting system for scientific and technological

Figure 2
Number of Graduates and Talents in Changzhou from 2003 to 2012[10]



Source: Adapted from Ma (2017).

innovation policy', 'five major innovative projects', '515 plan of high and new technology industry' issued to enhance regional innovation capability, Changzhou ecosystem conducted 534 national science and technology projects (obtained 413 million RMB funds), 774 provincial projects (obtained 956 million RMB funds), mainly with industry-research collaboration. During this stage, Changzhou also implemented the innovation platform for resource sharing, and a national innovation park focusing on R&D and patent application (Changzhou Bureau of Statistics, 2006–2010).

Stage Three

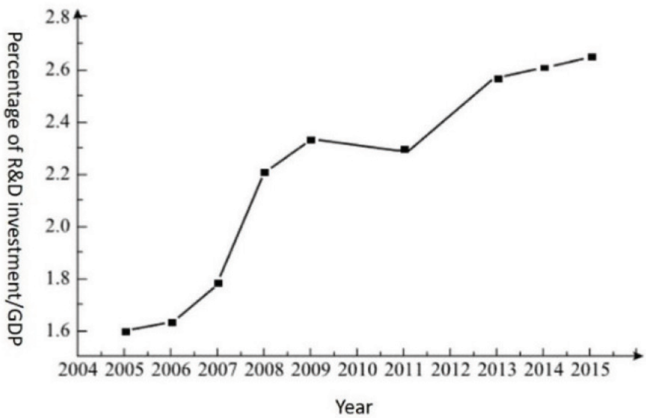
Stage three (2011–2015) was the expansion and extension of innovation ecosystem after reaching maturity and self-management. The main concern is to upgrade towards more value-added activities, and create more IP, in particular the economic sectors of intelligent manufacturing, carbon materials and new medicine sectors.

Under full coordination, the local government prioritised 10 major sectors to integrate the supply chain, which were rail transportation, automobile and spare parts, agricultural machinery and engineering machinery, solar photovoltaic, carbon materials, new medicine, new light source, general aviation, smart grid, intelligent numerical control and robot industries. As Changzhou model became successful, it was then upgraded and extended geographically, known as 'one core, two zones, three parks and multiple bases'. Among them, 'one core' is referred to Changzhou Science and Education City, 'two zones' meaning two national high-tech development zones to the South and North of Changzhou, 'three parks' including Zhongguancun Science and Technology Industrial Park, Changzhou West Taihu Science and Technology Industrial Park and Jintan Hualuogeng Science and Technology Industrial Park, and 'multiple bases' include 13 science and technology production clusters inside Jiangsu province.[11] Based on the extended network, 31 main incubators of start-up firms were further founded.[12]

In 2014 alone, there were 1,000 new patents from universities and firms, mainly from the sectors of intelligent manufacturing, carbon materials and new medicine. A total of 70 key technology breakthroughs also emerged in Changzhou. Meanwhile, the local government organised international conferences, assisting companies and R&D centres to collaborate with international partners from UK, Germany and Finland[13] in areas of bio-pharmaceutical, new energy and intelligent manufacturing, by issuing rewarding policies. In 2015, by signing the agreement 'China–Israel collaboration plan', the China–Israel Innovation Park was established in Changzhou, through which Israeli companies such as Hobart Group, Emefcy, Propel Design and Natali collaborated with Chinese companies in the area of medical technology, bio-energy, engineering and healthcare (data source: interview to Changzhou Science and Technology Bureau).

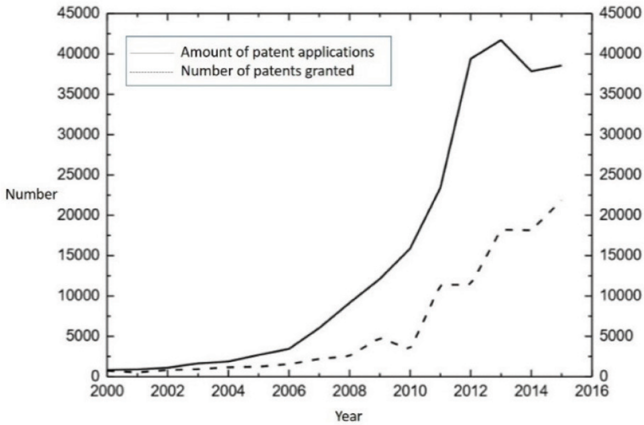
Statistics showed continuous growth of R&D investment directly from Changzhou local government and indirectly with the policy guidance (Figure 3) from 2004 to 2015. The amount of patent applications in Changzhou increased from 837 (year 2000) to 37,833 (year 2014), and the number of patents granted in 2014 reached 18,152, which was 24 times than year 2000 (Figure 4) (Changzhou Bureau of Statistics, 2017). Local innovation capability enhanced dramatically. From 2006 to 2010, there were 1,297 academic articles published (EI, SCI and ISTP) by Changzhou University, Jiangsu University of Technology and Changzhou Institute of Technology. The number of publication was 3,107 from 2011 to 2015[14] (data source: interview to Changzhou Science and Technology Bureau and Changzhou Science and Education City Administration Committee).

FIGURE 3
R&D Investment in Changzhou from 2004 to 2015



Source: Adapted from Ma (2017).

Figure 4
Number of Patent in Changzhou from 2000 to 2014



Source: Adapted from Ma (2017).

Based on this case study, we can summarise key events and local government policies at each stage of Changzhou innovation ecosystem (Table 2). The innovation ecosystem demonstrates a clear interaction among industry, university and research (Table 3).

University is the key knowledge resource of the ecosystem, as it provides training programme for industry, and graduates with skills. Though Changzhou region only had four universities and colleges before 2000, the government attracted other universities for seminars and forum. In addition, higher occupation education schools have continuously trained skillful personnel. Universities collaborate with industry for education. For example, Changzhou Vocational Institute of Engineering as undergraduate talent education base and industry staff continuing training base.

Industry plays the role of production and generating revenue for the ecosystem. In Changzhou region, most SMEs are nurtured or supported by the local government. They collaborate with universities for staff training and knowledge enhancement, meanwhile cooperating actively with research institutes for IP creation and technology transfer. For example, with government guidance, private firms jointly invested with the Chinese Academy of Sciences, and established a new company Zhong Jian Science and Technology Development Co., Ltd. This company focused on new product development and technology service of high performance carbon fibers, fabrics, composite materials and related products (data source: interview to Changzhou Science and Technology Bureau). Changzhou does not have Fortune 500 companies or MNEs, however with policy support, learning and international collaboration, private companies become strong. Taking Hengli Group for example, who ranks among top 500 strongest private enterprises in China. Founded in 1999, the company has expanded its product line from hydro cylinders to hydraulic components, precision castings, pneumatic components and hydraulic systems.

Table 2
Key Policies and Events in the Development of Changzhou Innovation Ecosystem

Stages	*Background in Changzhou*	*Concerns from Government*	*Key Events/Policies*	*Innovation Outcomes*
Stage One (2001–2005) Formation	Lack of innovation resources, including HR, technology, fund and innovation awareness.	Looking for approaches to combine university, industry and research → integrating resources in the region; introducing external resources.	(a) Science and technology infrastructure development: enterprise technology centres, engineering technology centres, postdoctoral workstations; (b) SME technology centres; (c) establishing science and technology forum; (d) issuing policies 'Changzhou manufacturing information engineering pilot implementation', 'Promoting the progress of science and technology,' reward system on 'science and technology'; (e) Establishing IPR bureau; (f) creating learning atmosphere; (g) Launching education programmes; (h) forming collaboration between universities and research centres.	400 industry-university-research interaction activities; 2000 collaboration projects; 31.3 billion RMB technology based trading; 112 service centres (Ma, 2017, p. 169).
Stage Two (2006–2010) Development/ Maturity	The original role of the government is not strong, lack of policy and capital investment. Firms have not yet become main innovation players; the upgrading of traditional industrial sectors are slow.	Forming new 'Changzhou model' with policies and research collaboration → co-development of university, industry and research centres; establishing 3-levels of innovation platform; attracting external resources.	(a) Establishing 'higher education park' for personnel training; (b) technology transfer and transformation; (c) transferring from 'university city' to 'science city'; (d) issuing 40 policies on innovation; (e) attracting talents through the '1,000 overseas talent' project; (f) Industry upgrading: for example, forming the PV industry chain; (g) providing subsidies to support independent innovation products; (h) development of VC, PE, risk compensation fund, specialised science and technology financial centres to provide service for SMEs; (i) development of science and technology oriented service industry.	4.13 billion RMB national fund (543 projects), 9.56 billion RMB provincial fund (2,514 projects); 90% R&D investment, 80% experts, 60% patents came from industry; annual growth rate of patent application was 45.6%; national and provincial prizes (Ma, 2017, p. 171).
Stage Three (2011–2015) Extension/ Expansion	More regional innovation based competition, lacking of independent IPR, brand and high-value added products.	Enriching 'Changzhou model' (reconfiguration and service enhancement) → collaborating with global resources; internationalisation	(a) Upgrading the industry-university-research park through '3,211', '4+1' projects; (b) internationalisation: Sino-US science and technology Park, German innovation centre, 'APEC 2014 Changzhou declaration', etc.; (c) identifying leading enterprises on innovation, transforming towards innovative city; (d) establishing innovation evaluation methods; promote patents; linking industry with financial institutions; (e) '518' Internet platform project; (f) focusing on 10 main industry chain development, inviting national research institutions; (g) HR management, for example, '323 entrepreneurial talent training plan'.	National and provincial prizes; in 2014 alone, 300 projects, 70 key technology breakthroughs; 1,000 patients, 10 billion RMB revenue; 3.5 million RMB from service sector (Ma, 2017, p. 173).

Source: Compiled from Ma (2017).

Table 3
Interaction Mechanism Among Industry, University and Research

Players	*Roles and Activities*	*Role of Local Government*
University	• HR training for industry. • Scientific research. • The transformation and industrialisation of scientific research to industry. • Education and research improvement through industry feedback.	• Investing on education programmes across universities. • Attracting outside universities and overseas experts for knowledge sharing, HR training and development. • Establishing education forum.
Industry	• Technology transfer and transformation. • Collaboration with research institutes for R&D. • Expanding existing patents and innovation outcomes.	• Encouraging companies to carry out research collaboratively with fiscal and taxation policies. • Helping with national and provincial project application. • Creating knowledge sharing platform. • Providing IP protection and other service. • Encouraging innovation and entrepreneurship.
Research	• Collaboration with university and industry. • Collaboration with outside research institutes such as China Academy of Sciences. • Establishing R&D centres with external partners. • Establishing bases for technology transfer, transformation and incubating enterprises.	• Helping to build laboratories and provide talent subsidies. • Providing funds to large R&D projects.

Source:

In 2005, it was listed on the Shanghai Stock Exchange (Stock Code: 601100), now having a market value of about 20 billion RMB. With 116 patents in 2016, Hengli has made its way into world leading hydraulic manufacturer (data source: interview to Hengli Group).

Research is a new player apart from the traditional triple helix model. It is the main resource of technology and patent, which enables technology transformation and communalisation for industry practice. In China, there are three types of research institutions, all observed in Changzhou innovation ecosystem: (a) research centres in university or jointly established by several universities, focusing on a specialised technology with potential industrial use. Examples include the Research Institute of Nanjing University (Target Pharma), Research Institute of Southwest Jiaotong University in Changzhou (Railway transportation equipment), Research Institute of Dalian University of Technology (Surface Engineering of Materials). (b) Public institutions funded by government, for instance the Changzhou Advanced Manufacturing Technology R&D and Industrialisation Center, Research Institute of NC Technology, Research Institute of Optoelectronic Technology in Changzhou.

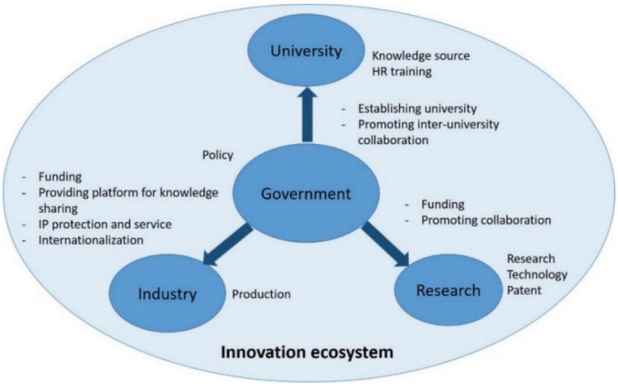
(c) R&D institutions funded by companies, or jointly by companies and universities (e.g., Changzhou Semiconductor Lighting Application Technology Institute, Zhong Jian Science and Technology Development Co., Ltd. Take the Changzhou Advanced Manufacturing Technology R&D and Industrialization Centre). It was jointly established by Changzhou government and China Academy of Sciences in November 2006. The centre has so far introduced more than 20 research centres of the China Academy of Sciences to set up branches in Changzhou, and to collaborate with local companies. Collaborating with industry, the centre has participated in 100 projects, achieving sales revenue of 1 billion RMB. Now, there are four main high-tech laboratories within Changzhou Advanced Manufacturing Technology R&D and Industrialization Centre: industrial robot system laboratory, the automatic detection and control technology of intelligent automation laboratory, and energy storage laboratory covering the field of robot production line, automation and renewable energy storage devices (data source: interview to Changzhou Advanced Manufacturing Technology R&D and Industrialization Centre).

In Changzhou innovation ecosystem, the local government plays essential role, as shown in Figure 5. Government initiate the plan, creating and integrating resources, issuing policies to support university, industry and research. In resource scare regions, local government can help establish universities, and support start-up companies. In addition, it provides fund to research institutions, who in return generate research outcome, advanced technology and patents for industry practice. Once university, industry and research institutions are established, government can further build platform for inter-organisational knowledge sharing, enriching the ecosystem by providing service such as IP protection and internationalisation guidance. As the ecosystem becomes mature, government then focus on sustainable development and maintain an innovative culture.

Combining different process stages, along with key role/resource (structural component of innovation ecosystem), and policy support (infrastructural component), we can map out the dynamic process of innovation ecosystem, and highlight the key decision making areas for policy makers (Figure 6).

Our findings contribute to the theory of innovation ecosystem from government policy and its interaction with university, industry and research perspectives. Though triple helix theories indicate the interaction among players in innovation ecosystem, especially university, industry and government, our findings highlight the dynamic role of government at different stages. It seems that government policy is specifically important at early stage of forming the ecosystem, whereas its impact gradually declines at mature stages later on. In addition, current studies on innovation and ecosystem are either exploring regions with existing knowledge resources (case of Silicon Valley), or the innovation of focal companies (case of Apple, Taiwan's Hsinchu Science Park). Our research looks into a region original with limited innovation capability, few numbers of universities and high-tech firms. This is a completely new phenomenon, the study of which can be of theoretical and practical value.

Figure 5
Role of Local Government in Innovation Ecosystem



Source:

Figure 6
The Process and Component of Innovation Ecosystem in Changzhou

	Formation Stage	Development/ Enrichment Stage	Expansion/Extension Stage
Role & Resource (Structural)	Talent development/training University/college development SMEs Capital	IP Product University/college SMEs and large firms R&D centres	R&D centres External partner Service agencies
Policy/Service Support (Infrastructural)	Promoting talent people Attracting investment Attracting local SMEs	Platform for knowledge sharing Feedback system Network improvement	Service platform Eternal collaboration network Culture and sustainability
Key Decision Making Areas	Policy is the key driver Top-down plan and control Inter-university collaboration	Policy improvement Towards self-management IP protection	New policy & rewarding system

Source:

Conclusion

This study aims to investigate the interaction between local government policy, university, industry and research in innovation ecosystem, based on regions where the original knowledge resource is limited. To explore the details, we adopted in-depth single case study, by investigating Changzhou City, China. This region had few numbers of universities, research institutes and leading firms before 2000; however, with local government support, a healthy, dynamic, diverse, fast-growing innovation ecosystem has developed, with inter-organisational knowledge sharing, joint new product development, internal and external collaboration. By reviewing policies issued by Changzhou Science and Technology Bureau, innovation events in Changzhou during 2001 and 2015, we have identified three stages of the of innovation ecosystem (Figure 6); analysed the impact of local government policy on Changzhou innovation ecosystem at different stages; and identified the interaction among players (government, university, industry, research) in the ecosystem (Figure 5).

Our research contributes to the theory of innovation ecosystem, by exploring the dynamic institutional and policy factors in emerging economies in shortage of knowledge resources. With data collection and analysis, we find that at early stage, local government plays a key role by providing overall planning, creating and integrating resources. As in the case of Changzhou city, the local government issued policies to attract talents from outside Changzhou, to form research centres and lead projects. Collectively learning is important, which can be achieved by organising inter-university forum and events. During the development and enrichment stage, the local government issued policies, continuously facilitating sharing and problem-solving among industry, university and research. These players give feedback to policy makers in return. Gradually the ecosystem can reach self-management with government infrastructure support, training and quality control and the emergence of service providers. Regulations such IP protection were improved. Finally, the government policy helped innovation ecosystem to expand towards internationalisation and upgrading to high-value added activities. We have found out structural and infrastructural elements of innovation ecosystem, in particular the changing roles of local government. It highlights the correlation among university, industry, research and government in knowledge creation, which also enriches the triple helix model. Government plays essential role in initiating innovation at early stage by establishing research centres, promoting inter-university and university-industry knowledge sharing. Whereas at later stages, government can facilitate the interaction among university, industry and research, who then become the most active players. In our case study, research is identified as a new important player in the innovation ecosystem, as it demonstrates different types based on Changzhou case study.

Apart from theoretical contribution, the staged model (Figure 5) can be valuable for policy makers in other resource scare regions to build dynamic innovation ecosystem. While traditional firms focus on in-house innovation, inter-firm collaboration including open innovation, we suggest that on a regional level, innovation ecosystem with government support can quickly absorbing resources, creating and sharing knowledge. It is highly important in cities where there are very few university resources, research centres and leading firms. As for the limitations of this research, single case study from one region may not be comprehensive, and data sources are mainly from documents and interviews with government officials, universities, research institutions and companies. More primary studies into other players in the ecosystem can enrich the findings. Also the unique economic and social structure of China has made government policy important in nurturing innovation ecosystem especially at early stage, which may not be the same situation in other countries. In fact, with the rapid advancement of technology and networking of companies, the collective interaction among university, industry, research, users with the joint influence from government policy, national culture and institutional factors can be one of the future research areas.

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Appendix A

Table A1
Samples Questions During Semi-structured Interviews

	Sample Questions
Government	• What are the main changes of science and technology related policies in recent 10 years? (both central government and local government policies) • At each stage, how these policies can influence company innovation? • How can policy attract internal and external talents? • What are the difficulties to share knowledge among university, industry and research? • How can policy help the innovation resources be transformed into industry capability?
University	• How to conduct co-training and talent development with companies? • What are the other interaction activities between university and industry (and research)? • How can local government support university-based innovation? • How to conduct collective learning with industry and research within the ecosystem?
Industry	• Patents, new products, new technology, new market in recent years? • What is the impact (benefits/constrains) of external environment, public service and policy? • Any external innovation and learning related activities? (Successful/unsuccessful stories?) • Knowledge capital management, technology transfer and value-added activities?
Research	• How to share and collaborate with industry/university? • How can local government policy support research and innovation? • How to transfer research outcomes to industry capability? With help of government?

Source:

NOTES

1. Changzhou is a city in the south of Jiangsu Province. It has a total area of 4,373 square kilometers, population of 4.7 million, GDP 6,622.3 billion RMB (year 2017), and more than 80,000 private enterprises. (http://www.changzhou.gov.cn/)
2. In 2010, 'regional development plan for the Yangtze River Delta region' was approved by the The National Development and Reform Commission of the People's Republic of China (NDRC) (No. 1243, Year 2010), making it clear that 'Changzhou should give fully make the advantages of industry, science and education, building an advanced manufacturing base and an important innovative city based on equipment manufacturing, new energy and new materials'. In 2016 NDRC approved the 'Yangtze River Delta urban agglomeration development and plan' (No. 1176, Year 2016).
3. Tsinghua University, established in 1911 Beijing, one of China's most renowned universities. (http://www.tsinghua.edu.cn)
4. Peking University, founded in1980 Beijing, a comprehensive and national key university. (http://www.pku.edu.cn/)
5. Southeast University, based in Nanjing, a national leading university in engineering. (http://www.seu.edu.cn/)
6. Xi'an Jiaotong University, based in Xi'an, strong in engineering, technology and management. (http://www.xjtu.edu.cn/)
7. Zhejiang University, founded in 1897 Hangzhou, one of China's oldest and most prestigious universities. (http://www.zju.edu.cn/)
8. Chinese Academy of Sciences, headquartered in Beijing with branches all over China, national leading research organization. (http://www.cas.cn/)
9. Changzhou College of Information Technology, Changzhou Vocational Institute of Textile and Garment, Changzhou Vocational Institute of Engineering, Changzhou Vocational Institute of Light Industry and Changzhou Institute of Mechatronic Technology.
10. Some data missing due to different statistical calibers.
11. Smart City Science Park, High-end Equipment Science and Technology Industrial Park, New Material Science and Technology Industrial Park, Photovoltaic Science and Technology Industrial Park, Biological Science and Technology Industrial Park, Hua Luogeng Science Park, Zhongguancun Science and Technology Industrial Park, China-Israel Innovation Park, Rail Transportation Science and Technology Industrial Park, Tianning Science and Technology Industrial Park, Electronic Information Science and Technology Industrial Park, Energy and Environmental Technology Industrial Park and Intelligent Equipment science and Technology Industrial Park.
12. Changzhou High-tech Entrepreneurship Service Center, Changzhou Sanjing IT Incubator, Changzhou Software Park (creative industry incubator), Changzhou Biopharmaceutical Incubator, Changzhou Xixiaye Tool Industry Entrepreneurship Service Center, Changzhou Longhu High-tech Entrepreneurship Service Center, Jiangsu Changzhou Biopharmaceutical Equipment Science and Technology Park, Wujin Hi-tech Entrepreneurship Service Center, Changzhou National University Science Park, Changzhou Wujin Science Incubation Park, Zhonglou District Innovation Service Center, Changzhou West Taihu International Wisdom Park, Jiangsu Jintong IT Incubator and Changzhou Tianan Digital City Science and Technology.
13. Entrepreneurship Service Center, Changzhou Science and Education City International Innovation incubator, Changzhou Xinzha Technology Entrepreneurship Service Center, Changzhou Canal No. 5 Creative Industry Incubator, 1,000 People Plan (Changzhou) New Energy Automobile Research Institute Business Incubator, Changzhou Tianning High-tech Entrepreneurship Service Center, Changzhou Tianning New Dynamic High-tech Entrepreneurship Service Center, Changzhou Longcheng Student Entrepreneurship Technology Incubator, Changzhou Hengsheng Science Park, Changzhou Heimudan High-tech Entrepreneurship Service Center, Changzhou California Science and Technology Port Electronic Software Specialized Incubator, Jintan Hi-tech Entrepreneurship Service Center, Jintan Hongtai Science Park, Liyang High-tech Entrepreneurship Center, Liyang Tianmu Lake Mechanical and Electrical Entrepreneurship Park, Changzhou High-tech Zone

Technology Enterprise Accelerator, Changzhou Science and Education City Science and Technology Enterprise Accelerator and Changzhou Western Taihu Biopharmaceutical Industry Science and Technology Enterprise Accelerator.

14. The number of article published by Hohai University (Changzhou campus) is not included in Changzhou, but in its headquarter (Nanjing) statistics.

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