Journal of Infrastructure, Policy and Development (2022) Volume 6 Issue 2.
DOI: 10.24294/jipd.v6i2.1661

ORIGINAL ARTICLE

Dynamic capabilities perspective on innovation ecosystem of China's universities in the age of artificial intelligence: Policy-based analysis

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ABSTRACT

Universities play a key role in university-industry-government interactions and are important in innovation ecosystem studies. Universities are also expected to engage with industries and governments and contribute to economic development. In the age of artificial intelligence (AI), governments have introduced relevant policies regarding the AI-enabled innovation ecosystem in universities. Previous studies have not focused on the provision of a dynamic capabilities perspective on such an ecosystem based on policy analysis. This research work takes China as a case and provides a framework of AI-enabled dynamic capabilities to guide how universities should manage this based on China's AI policy analysis. Drawing on two main concepts, which are the innovation ecosystem and dynamic capabilities, we analyzed the importance of the AI-enabled innovation ecosystem in universities with governance regulations, shedding light on the theoretical framework that is simultaneously analytical and normative, practical, and policy-relevant. We conducted a text analysis of policy instruments to illustrate the specificities of the AI innovation ecosystem in China's universities. This allowed us to address the complexity of emerging environments of innovation and draw meaningful conclusions. The results show the broad adoption of AI in a favorable context, where talents and governance are boosting the advance of such an ecosystem in China's universities.

Keywords: *dynamic capability; innovation ecosystem; universities; artificial intelligence; policy instruments; policy stakeholders; text analysis*

1. Introduction

Artificial intelligence (AI) has evolved from being just a "technological fancy trend" to becoming "an international field of competition" (Arenal et al., 2020, p. 1). This new paradigm has been seen as a new industrial revolution with its ability to transform economies and societies, which are the elements of national strength (Arenal et al., 2020). Several nations have introduced AI policies with AI strategies in documents such as China's "The New-Generation Artificial Intelligence Development Plan" (State Council of the People's Republic of China, 2017); the United States' "The National Artificial Intelligence Research and Development Strategic Plan" (National Science and Technology Council, 2016); the European Union's "Robotics 2020—

ARTICLE INFO
Received: September 15, 2022
Accepted: November 14, 2022
Available online: December 2, 2022

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Multi-Annual Roadmap for Robotics in Europe" (SPARC, 2016) and "Civil Law Rules on Robotics" (European Parliament, 2016); the UK's "RAS 2020–Robotics and Autonomous Systems" (Remote Applications in Challenging Environments, n.d.), "Industrial Strategy: Building a Britain Fit for the Future" (Department for Business, Energy & Industrial Strategy, 2017), and "Growing the Artificial Intelligence Industry in the UK" (Hall and Presenti, 2017); and Japan's "Artificial Intelligence Technology Strategy" (Strategic Council for AI Technology, 2017). In doing so, AI, as a strategic industry, is crucial for enhancing economic development, national security, and governance (Barton et al., 2017; Kewalramani, 2018). This global trend is largely led by the two largest technology competitors: the US and China (Kewalramani, 2018). Nevertheless, China's AI, in particular, showcases a technology-based approach to economics and politics with a different slant from the US. This is highlighted in the foundation of social harmony, and the strict control of national laws on cyberspace applications or the use of AI-related technologies (Arenal et al., 2020). More importantly, these plans rely heavily both on supply-side policies for research and education and on a technology-driven view of innovation (Serger and Breidne, 2007). Moreover, due to China's leadership position, AI has been applied in a broader range of sectors, including defense and social welfare, and has been expected to lead to more efficient products and services, achieving large productivity gains and a more dynamic economy (Arenal et al., 2020; Barton et al., 2017).

Recently, AI has sparked concern among policymakers about education in China, such as the "Action Plan for Artificial Intelligence Innovation in Higher Education" (Ministry of Education of the People's Republic of China, 2018), and the United States' Office of Educational Technology, which works to develop policies and supports focused on the effective, safe, and fair use of AI-enabled educational technology. Furthermore, Huai Jinpeng, Minister of Education of the People's Republic of China, highlighted that China will increase the supply of AI education policies, promote digital transformation, intelligent upgrading, and integrated innovation in education, and speed up the building of a high-quality education system (Ministry of Education of the People's Republic of China, 2021). It is necessary that AI engages with innovation activities when researchers adopt an innovation ecosystem, especially in university-industry-government interactions. Hence, studying the innovation ecosystem based on China's AI policies arouses the interest of researchers. However, previous studies focused on China's AI around the government dimension, and research on the innovation ecosystem in universities, from the perspective of dynamic capabilities, based on policy analysis, is limited.

CITATION
Qu C and Kim E (2022). "Dynamic capabilities perspective on innovation ecosystem of China's universities in the age of artificial intelligence: Policy-based analysis". *Journal of Infrastructure, Policy and Development*, 6(2): 1661. doi: 10.24294/jipd.v6i2.1661

Consequently, this research work takes China as a case study and provides a framework of AI-enabled dynamic capabilities to guide how universities should manage their innovation ecosystem based on China's AI policy analysis. The objective of this paper is to present a description of the theoretical research status of AI drawing on two theories: dynamic capabilities and innovation ecosystem. Second, it aimed to analyze the role of universities in the age of AI, by means of a text analysis of China's national and regional AI policies. Third, based on the foundations of dynamic capabilities and innovation ecosystem theories, we critically synthesized existing theories and developed an asymmetric quadruple helix (AQH) model for the purpose of revisiting the AI innovation ecosystem in China. Last, this research work adopted the analysis of policy instruments and policy stakeholders, thereby discovering insights from different dimensions of AI-related policy interpretations. In particular, this paper examined how government, universities, and industries, as policy stakeholders, act in different dimensions of policy instruments. More specifically, a sub-objective was to further enhance the understanding of the governmental-university-industry interaction in China and emphasize the importance of the AI-enabled innovation ecosystem in universities with governance regulation, thereby permitting the authors to address the complexity of emerging environments of innovation to draw meaningful conclusions.

2. Review of literature

2.1. Theoretical context

Different theories exist in the literature regarding the innovation ecosystem and dynamic capabilities. Previous studies linking dynamic capabilities with the innovation ecosystem can be seen in **Table 1**, which illustrates the main concepts of dynamic capabilities and the innovation ecosystem from current academic papers. There are two categories to the existing literature: management (e.g., Faccin et al., 2022; Feng et al., 2019; Guenduez and Mergel, 2022; Heaton et al., 2019; Y. Jiang et al., 2021; Robertson et al., 2021; Teece, 2018, 2010), and digital transformation (e.g., Q. Jiang and McCabe, 2021; Kaiser et al., 2021; Macher and Mowery, 2009; Warner and Wäger, 2019; Xie et al., 2022; D. Zhang et al., 2022). It is obvious that the research on management domains is always approached from a digitalization context (Fisher, 2016), and journals with the title "management" more or less contain research on digitization (e.g., Journal of Management, Academy of Management Journal, Project of Management Journal, etc.). Therefore, it was meaningful to focus on dynamic capabilities and the innovation ecosystem in the management field in the digitization context.

Furthermore, we input the keywords of "dynamic capability" and "innovation ecosystem" in the Scopus database for searching articles. Then we used VOSviewer to present a visual map of keywords for the 506 related academic articles regarding dynamic capabilities and the innovation ecosystem in the domain of social sciences (**Figure 1**). It shows that artificial intelligence, innovation, and China are keywords with a higher occurrence in the research field. Therefore, based on the keywords, we identified AI, innovation, and China as our research targets, linking the theories of dynamic capabilities with the innovation ecosystem. However, these articles or previous studies did not integrate AI with dynamic capabilities to explore China's innovation ecosystem in universities. Thus, we approached it from a dynamic capabilities perspective on the innovation ecosystem of China's universities in the age of AI through policy analysis.

Table 1. Recent research works linking dynamic capabilities with innovation ecosystem

Authors, year	Concept	Domain
Kaiser et al., 2021	Data-driven value creation in the automotive ecosystem must be achieved through collaboration among various stakeholders in vehicle data-driven services	Digital transformation
Q. Jiang and McCabe, 2021; Macher and Mowery, 2009	Technologies can contribute indirectly through enhancement of dynamic capabilities	Digital transformation
Xie et al., 2022	The mechanism of how digital platforms affect SMEs' business model innovation by leveraging dynamic capabilities	Digital transformation
D. Zhang et al., 2022	The growth mechanism and evolution path of dynamic capabilities affecting enterprise niche change in the process of cross-boundary innovation of SMEs under the background of digital transformation	Digital transformation
Warner and Wäger, 2019	Dynamic capabilities for digital transformation are in the navigating of the innovation ecosystem	Digital transformation
Y. Jiang et al., 2021	Tourism organizations utilize dynamic capabilities to develop resilience in a disaster context can be applied to broader proactive management experience	Management
Guenduez and Mergel, 2022	Dynamic management can play a crucial role for the ecosystem innovation in smart cities	Management
Robertson et al., 2021	The effect of knowledge-based dynamic capabilities that act as drivers of innovation performance in the innovation ecosystem	Management
Heaton et al., 2019	The cultivation of strong dynamic capabilities by the university and its leaders will help to sustain and enhance the campus' innovation ecosystem	Management
Faccin et al., 2022	Universities use dynamic capabilities to take on the role of fostering and orchestrating the recovery of the regional innovation ecosystem	Management
Feng et al., 2019	The dynamic capabilities of a company play a key role, resulting in the establishment or development of the innovation ecosystem during the evolutionary process	Management

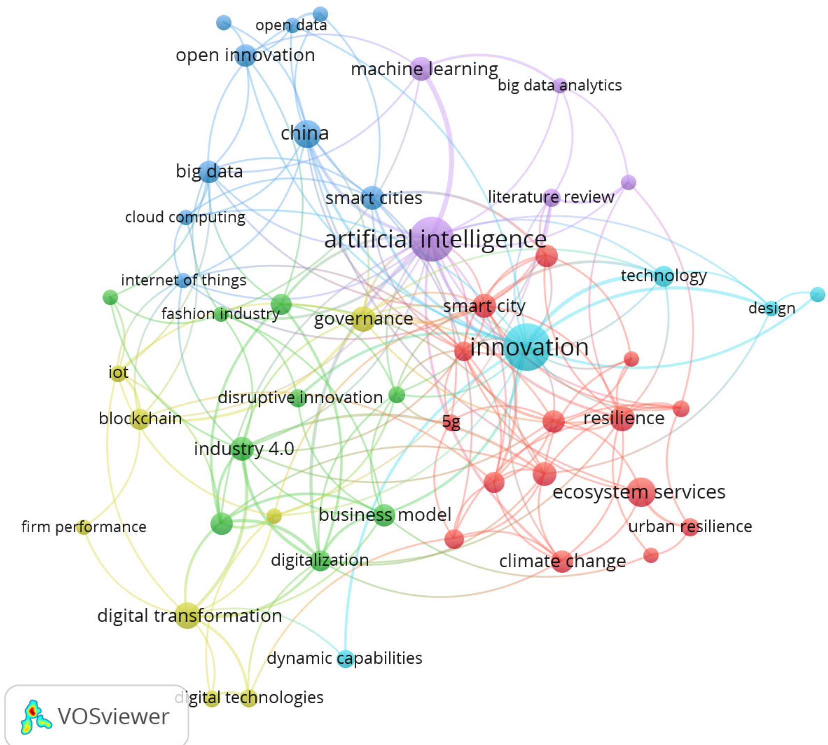

Figure 1. Occurrence of keywords of "dynamic capability" and "innovation ecosystem" in Scopus

2.2. Theories of dynamic capabilities

Dynamic capabilities are an important theoretical lens that allows researchers to explore the management of an ecosystem from an organizational perspective. Theories of dynamic capabilities provide a rich firm-level literature base, including managerial processes (e.g., Ambrosini and Bowman, 2009; Peteraf et al., 2013; Teece, 2020, 2018, 2010; Dal Zotto, 2003), organizational routine (e.g., Eisenhardt and Martin, 2000; Peteraf et al., 2013; Rindova and Kotha, 2001), knowledge management (e.g., Cepeda and Vera, 2007; Zollo and Winter, 2002), and organizational learning (Easterby-Smith and Prieto, 2008; Weerawardena et al., 2007). These works of literature, represented by Teece et al. (1997) and Teece (2007), emphasized the significant role of the resource base that tends to attach multiple issues and solutions of strategic management to its reconfiguration and recombination (e.g., financial resource, human resource, and knowledge resource). Dynamic capabilities are affected by resource condition, experience, and learning abilities, and it is believed that dynamic capabilities and competitive advantage have a direct connection. More importantly, dynamic capabilities are of the evolutionary view that the resource and capabilities inside an organization ought to be always changing. While Eisenhardt and Martin (2000) agreed with the resource-based views of Teece et al. (1997) and Teece (2007), they critiqued the definitions of dynamic capabilities and attempted to specify the managerial process by breaking down dynamic capabilities into product development, decision making, and alliancing capability. Thus, the theory of dynamic capabilities is an identifiable and specific routine.

Generally, the dominant idea of this theory is to seek the managerial capability, which allows firms to integrate and reconfigure their internal and external resources, thereby ultimately achieving competitive advantage. Based on this understanding, in this study, we applied it to "organizations-universities" (Frank, 2009, p. 1). Therefore, we can understand that the core idea of the theories of dynamic capabilities echoes the need for better explaining the value capture within an ecosystem. Hence, we decided to adopt this theory and explore the management of external actors within an ecosystem from a university perspective.

2.3. Innovation ecosystem in universities

The concepts of ecosystems come into being in universities (Adner, 2006; Arenal et al., 2020), which can be regarded as one kind of innovation stakeholder (Frenkel and Maital, 2014). Innovation ecosystems can be discovered in many articles in recent years. Among the current articles, most mentioned the triple helix (TH) model (Etzkowitz and Leydesdorff, 2000, as cited in Arenal et al., 2020), which is widely adopted and cited for the environment and characterizing the relationships among the main stakeholders of the innovation ecosystem (Chinta and Sussan, 2018; Pique et al., 2018, as cited in Arenal et al., 2020). The TH model as a "descriptive and prescriptive model" (Heaton et al., 2019, p. 922) was first proposed for the university-industry-government relationship by Etzkowitz and Leydesdorff (1995) and aims to highlight how the interaction between the three key institutions of university, industry, and government evolves in the process of knowledge-based innovation. Other approaches to the roles of universities are regional innovation systems (Asheim et al., 2011) and the entrepreneurial university (Audretsch, 2014), but these approaches fail to consider that the characteristics of universities differ. Therefore, these characteristics (research skills, resources, etc.) need to be considered when analyzing universities' engagement with the regional ecosystem, because "engagement is so context-dependent" (Benneworth et al., 2016, p. 731). Considering these unstable factors, universities need strong dynamic capabilities to strategically apply their "knowledge, reputation, and financial capital to build and maintain strong ecosystems" (Heaton et al., 2019, p. 922). While this concept has been applied to universities and has been related to the innovation ecosystem, few studies make a breakthrough in the technological context. As previously mentioned in the section on theoretical context, digitization influences innovations in various industries. Hence, to explore the dynamic capabilities of universities in the innovation ecosystem, AI, as the mainstream of digitization, is non-neglected. Moreover, due to China's leadership position in the AI field (Allen, 2019; Kewalramani, 2018), how China's governmental initiatives work as innovation engines in universities is worth analyzing. However, previous studies have not conducted a policy-based analysis. As a result, there is still a gap between the mainstream discussion around the role of universities and how AI policies regarding the innovation ecosystem in universities drive them to increase their dynamic capabilities.

2.4. Evaluation of China's AI policies

According to the AI policies introduced between 2018 and 2021, such as the "Beijing Action Plan to Promote the Integration of Artificial Intelligence and Education" by the Beijing Municipal Education Commission and "The Construction of a National AI Innovation and Application Pilot Zone" by the Beijing Municipal People's Government, the key words frequently mentioned are "higher education", "universities", and "research institutions". These policies emphasize that the governments will thoroughly study the legislative works in AI applications and guide research and university institutions to follow relevant principles and laws when developing AI (Yang and Huang, 2022). They also highlight that universities play a key role in university-industry-government interactions (Cai et al., 2020; Etzkowitz, 2003; Heaton et al., 2019; Li and Fang, 2019). The traditional analysis of the role of universities uses the TH model, which emphasizes the third role of universities as having a synergistic effect (Cai and Liu , 2015; Zhang and Ding, 2014; Heaton et al., 2019; Li and Chu, 2022). Developing countries achieve rapid development with the support of the local political economy, while universities increasingly become the source of regional economic development (Etzkowitz, 2003). However, in this policy-based context, the TH model is not necessarily enough for research on the AI innovation ecosystem in China because the characteristics of the TH model in China are that universities and enterprises engage in research-university-industry activities in an organization and that the intervention of AI is bound to affect the relationship between the two institutions. Thus, Arenal et al. (2020) developed an asymmetric triple helix (ATH) model for the AI ecosystem in China from the country and industry levels based on Cai and Liu (2015) TH model, which focuses on capturing a regional innovation system (see **Figure 2**). Their framework emphasizes the central position of governments but leaves more room for regional and local governments to conduct their policy experiments (Arenal et al., 2020). In addition, except for re-examining the types of companies, they highlight the role of universities in producing new knowledge and training people. Unlike the TH model, in which government intervention comes after the initial university-industry collaborations, in the ATH model, the central government draws up a strategic plan and pools a range of resources to support AI development across the country before AI clusters begin to emerge on their own (Arenal et al., 2020). However, previous studies have not used the method of policy content analysis to discover the coordinating role of the government on the university ecosystem, especially the leveraging role played by the above-mentioned AI policy content on universities and industries. We emphasize that dynamic capabilities play an extremely important role in the ecosystem of universities. Therefore, a thorough understanding of AI policies is conducive to the development of technological innovation and the discourse power of universities in cooperation with enterprises. This study used policy instruments to analyze the dynamic balancing ability of universities under the understanding of China's AI policies.

2.5. Research gap

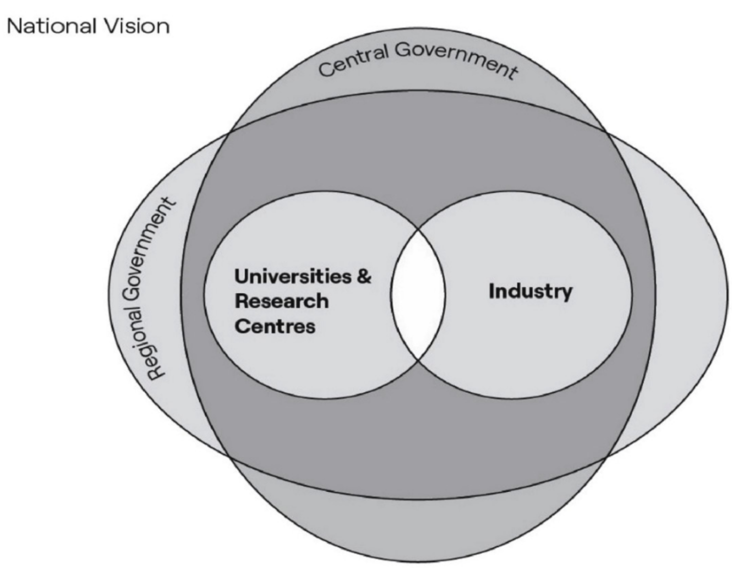

Figure 2. Asymmetric triple helix (ATH) model for AI ecosystem in China (Arenal et al., 2020)

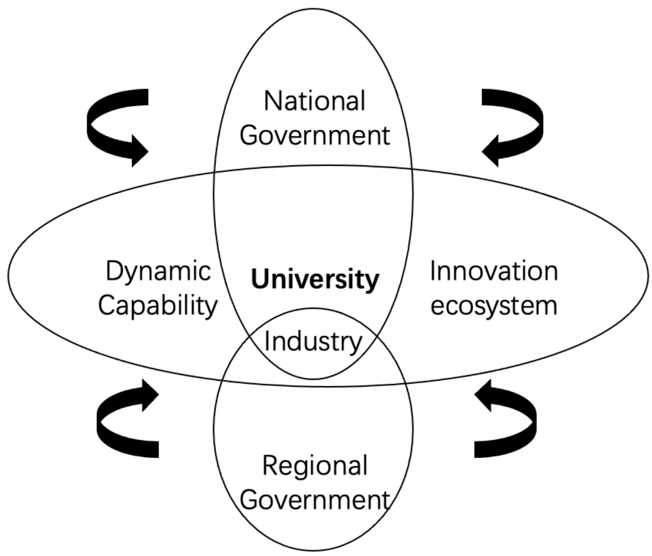

Figure 3. Asymmetric quadruple helix (AQH) model for AI ecosystem in China
Source: Own elaboration adapted from Arenal et al. (2020)

The above theories depict the importance of dynamic capabilities in the innovation ecosystem from different authors' perspectives. However, the research on Chinese universities' innovation ecosystem through AI policy analysis is limited. In particular, the concept of innovation ecosystem has been used to study the environment, but very little research has been undertaken from the perspective of dynamic capabilities. Etzkowitz and Leydesdorff (1995) defined the "triple helix" of academic-industry-government relations as probably being "a key component of any national or multi-national innovation strategy in the late twentieth century" (p. 2). This relation reflects the interaction between universities or research institutions and companies both in technology policies and studies. How these three dimensions are involved in the cooperation and their roles in the development of innovation, as previously mentioned, may differ because the relations rely on the changing context, research domains, and government property. Arenal et al. (2020) developed the "triple helix" model into an "asymmetric triple helix" to highlight these dynamic interactions. We also argue that this model still needs to be explored by analyzing China's AI policy instruments to discover the trends within these policies.

Therefore, this research work aimed to fill these gaps by developing an optimized AQH model for the innovation ecosystem in universities with governance regulations (**Figure 3**), drawing on the two main concepts of the innovation ecosystem and dynamic capabilities. This model integrated China's AI policy analysis, highlighting the key roles of universities or research institutions in the innovation ecosystem in the age of AI, thereby testing how China's government uses policy instruments to strengthen the role of universities in them.

3. Methodology

This research work explored the characteristics of AI policies and illustrated the specificities of the AI innovation ecosystem in China's universities, thereby permitting the researchers to address the complexity of emerging environments of innovation and draw meaningful conclusions. After the literature review on dynamic capabilities, the innovation ecosystem approach, and the suitability of the ATH model for the case of China's AI ecosystem, the next step was building hieratical coding using NVivo for text analysis to integrate experts' interpretation of the government's AI policies. In brief, it entailed three steps: data sampling, framework conduction, and document coding.

3.1. Data sampling

We retrieved the interpretations of experts and policymakers from the State Council Policy Database (http://www.gov.cn), PKULaw Database (http://www.pkulaw.com), Cyberspace Administration of China Database (http://www.cac.gov.cn), and provincial, municipal, and district local government databases (e.g., http://www.xunhui.gov.cn). We constructed a series of search terms designed to collect AI policy documents in China comprehensively, and the resulting documents were screened based on expert opinions. The policies were introduced from 2017 to 2022 because of the emergence of booming amounts of policies since the 2017 "New-Generation Artificial Intelligence Development Plan". Fifty-two relevant documents were initially collected, but for reliability and validity, this research work adopted two principles to further tease out and screen the selected policy documents. First, invalid policies were dismantled, such as repeated interpretations of government policies. Thus, we eliminated six invalid policies by checking the validity of the collected policies. Second, this study utilized qualitative content analysis, in which the initial work with the text involved "reading" and "analyzing the text in light of the research question" (Kuckartz, 2014, p. 51), and "thinking about whether and how documents can serve the research purpose" (Glenn, 2009, as cited in Yue et al., 2020, p. 5). To address the research questions and purpose, we selected the content of policy documents as a key reference index. After reading all of China's policy documents, 46 AI-related documents were selected.

3.2. Analytical framework

Policy instruments are "the carrier of policy". First, we commenced with an X dimension of policy instruments that are commonly adopted by policy stakeholders to achieve one or more policy objectives and thus realize the responsibility of the government (Zhu et al., 2022). Borrás and Edquist (2013) argued that regulations, economic transfers, and soft instruments are the three types of innovation policy instruments that are used as tools to influence the innovation process by public organizations. Rothwell and Zegveld (1985) claimed that the supply side, environmental side, and demand side are the three types of instruments, and that even if the policy instruments form a joint force, its effect will be maximized. Here, we classified the three types of instruments as selective coding hierarchically, according to Rothwell and Zegveld's (1985) classification, because China's AI policies include innovation activities and link them with social activities, such as public service and infrastructure construction (**Table 2**).

Second, we created a Y dimension of policy stakeholders to form a clear understanding of the roles of providers in China's AI policies. A stakeholder is a person who is engaged in real social activities and changes the world in some way, not from the perspective of philosophy but from the sociological point of view. The stakeholder refers to the people and groups engaged in practical activities in certain social relations (Yao et al., 2021). Here, we categorized policy stakeholders into three dimensions: regulators (government), providers (university), and demanders (industries) (see **Table 3**).

Regulators refer to the "central ministries and commissions" (Yue et al., 2020, p. 7), such as

Table 2. X dimension of policy instruments

Policy instrument	Elements of instrument	Policy items (*N* = 202)
Supply side	Innovation support system	BJ1-6, BJ1-9, CZ1-3, CZ1-4, GZ1-2, GZ1-5, HZ1-3, HZ3-9, LN1-3, LN1-9, QD1-2, QD1-3, QD2-4, SZ1-2, TJ2-3
	Public service	CD1-5, CZ1-8, G4-3, G5-7, G6-2, JS1-2, JS1-3, LN1-4, QD1-5, SZ2-3
	Infrastructure construction	AH1-3, CD1-2, CD1-4, CZ1-2, G1-2, G4-1, G5-4, G7-2, GZ1-3, HN1-1, HN1-2, HZ1-4, HZ3-10, LN1-2, QD2-3, SZ1-2, TJ1-2, ZJ1-3
	Science and technology information support	AH1-10, AH1-4, BJ1-2, CD1-3, CZ1-5, G5-2, YN1-3
	Talent cultivation	AH1-9, CS1-3, CZ1-9, G10-2, G2-5, G3-1, G5-5, G6-5, G7-6, G8-3, GZ1-6, HZ3-2, HZ3-8, JS1-4, LN1-8, QD1-6, QD1-9, SY1-3, SZ2-4, TJ1-6, TJ2-4, YN1-5, ZJ1-5
	Capital investment	AH1-5, CD1-7, CS1-1, DL1-5, G10-3, G2-2, G6-4, G7-3, HN1-4, HZ3-1, HZ3-11, HZ3-3, HZ3-4, HZ3-5, LN1-7, SZ1-3, TJ1-5, YN1-6
Environmental side	Strategic measures	CY1-3, HZ1-7, TJ1-3
	Finance support	CS1-4, G5-6, HZ3-7, SY1-2, ZJ1-6
	Goal setting	AH1-1, AH1-2, BJ1-1, BJ1-8, CD1-1, CY1-1, CY1-2, CZ1-1, DL1-1, G10-1, G1-1, G2-1, G5-1, G6-1, G6-2, G8-1, G9-1, GZ1-1, HZ1-1, HZ1-6, LN1-1, QD1-1, QD2-1, SY1-1, SZ1-1, SZ2-1, TJ1-1, YN1-1, ZJ1-1
	Policy support	CD1-5, G1-3, G7-1, JS1-5, ZJ1-7
	Intellectual property	CZ1-10, CZ1-6, G2-3, G2-4, G5-8, SZ2-2, SZ2-5, TJ2-5
	System construction	CY1-4, CZ1-12, G4-4, G4-5, HZ3-6
	Organization management	AH1-6, CD1-6, G6-3, HZ3-13, LN1-6, YN1-7
Demand side	Research cooperation	AH1-8, CZ1-11, CZ1-7, DL1-3, G1-4, G2-6, GZ1-4, HZ1-5, HZ2-2, QD1-4, QD1-8, QD2-2, SZ1-5, ZJ1-4
	Trial project	AH1-7, BJ1-5, BJ1-7, CS1-2, DL1-2, DL1-4, DL1-6, G5-3, G7-4, G8-2, HN1-3, HZ1-2, HZ2-1, JS1-1, QD1-7, QD2-3, SZ1-1, SZ1-4, TJ2-1, TJ2-2, YN1-2, YN1-8, ZJ1-2
	Information communications	BJ1-3, BJ1-4, G4-2, G4-6, G6-6, G7-5, G8-4, HZ3-12, LN1-5, SZ1-6, TJ1-4, TJ1-7, YN1-4

policymakers and interpreters. For example, the State Council has overall responsibility for national policy and administration. The Ministry of Science and Technology (MST) of the People's Republic of China implements the principles, policies, decisions, and arrangements of the Central Committee on scientific and technological innovation and upholds and strengthens the centralized and unified leadership of the Party over scientific and technological innovation in the course of fulfilling its

Table 3. Y dimension of policy stakeholders

Policy Stakeholder	Implication
Regulators	Government-lead
Providers	Universities, research institutions, agencies (financial institutions, incubators, and other institutions)
Demanders	Industries, market perspectives

responsibilities. The Cyberspace Administration of China is primarily in charge of cyberspace security and internet content regulation. Its major functions are directing, coordinating, and supervising online content management and handling administrative approval of businesses related to online news reporting. We adopted universities or research institutions as providers because they provide AI knowledge to students, and AI talents to industries. Demanders can be regarded as industries here, from the market perspective, in that industries require AI talents for the construction and development of different kinds of industries in China. Furthermore, as we mentioned earlier, government, universities, and industries make a holistic ecosystem in an organization (Arenal et al., 2020; Cai et al., 2020; Etzkowitz, 2003; Etzkowitz and Leydesdorff, 1995; Zhang and Ding, 2014; Li and Fang, 2019; Y. Zhang et al., 2019); thus, we tested its reliability and validity by creating the Y dimension of policy stakeholders.

Last, according to the X of AI policy instrument and the Y dimension of AI policies, we developed a matrix framework of policy analysis (**Figure 4**), based on the result of the distribution of AI policies stakeholders.

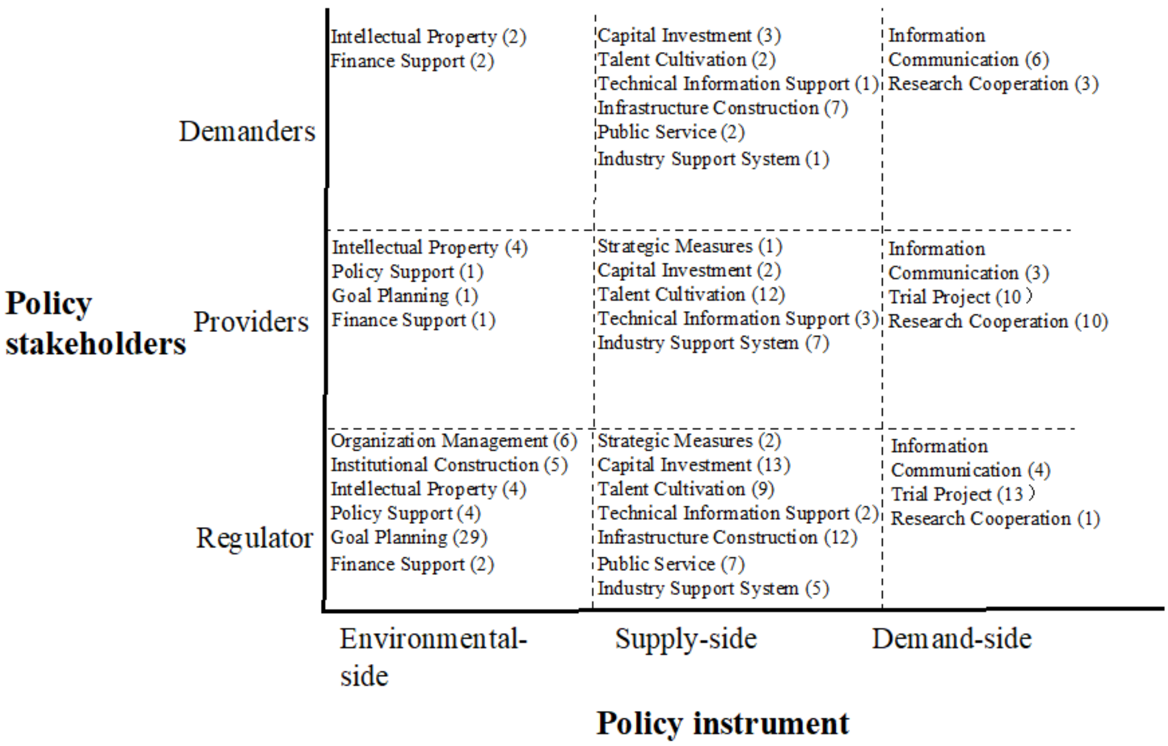

Figure 4. Matrix framework for AI policies ($N = 202$)

3.3. Document coding steps

Coding means that data is labeled and systematized with systematic, simplified, and repeatable characteristics (Köhler et al., 2022). It can help researchers give meaning to the raw data, make the data understandable (Elliot, 2018), and enrich the idea and theories by engaging more with the data (Locke et al., 2022). This research work followed the three-level coding steps of setting nodes, encoding with software, and validity test.

First, we collected experts' interpretations of AI policy and set nodes by the named title based on the three dimensions of policy instruments, and then we put the encoded content into the predetermined node. For example, we named the interpretation of "Innovation of Science and Technology Development Planning" (Changzhou Municipal People's Government) as "CZ" and the first piece of interpretation corresponding to each of the three types was named CZ1-1. Then we put this piece of content to the corresponding dimension of policy instruments. Second, to guarantee accuracy, we used NVivo software to conduct a qualitative content analysis. Third, we invited an external policy analyst as a peer reviewer to ensure the validity of the coding.

4. Findings

4.1. Overall analysis of China's policy instruments

The number of coded references can describe the frequency of use of the policy instruments. We queried the coded references of every node and calculated the proportion of different policy instruments in the total policy document. The results are shown in **Table 4**. We can see that the supply-side policy instruments include six elements: innovation support system (15), public service (10), infrastructure construction (18), science and technology information support (7), talent cultivation (23), and capital investment (18). There are seven items included on the environmental side: strategic measures (3), finance support (5), goal setting (29), policy support (5), intellectual property (8), system construction (5), and organization management (6). The demand-side instruments consist of three items: research cooperation (14), trial project (23), and information communications (13). Specifically, the most focused instruments are goal setting, which is included on the environmental side; talent cultivation, which is included on the supply side; and the trial project, which is included on the demand side.

4.2. Description of dimension of stakeholders

Table 5 shows the distribution and frequency of AI policies in each dimension. These policies provide comprehensive intervention in the main stage of AI construction in various regions in China, including the dimension of regulators (58.41%), providers (27.23%), and demanders (14.36%). Specifically, regulators that are government-led take the largest proportion in the Y dimension, which refers to the government's own collaborative governance, such as industrial development planning, implementation of national strategies, and government coordination in all the dimensions. This proves that when the central government develops a strategic plan and pools a range of resources to support AI development across the country, AI clusters begin to emerge on their own (Arenal et al., 2020).

Table 4. Frequency of policy instrument

Policy instrument	Elements of instrument	Coded node	Percentage
Supply side	Innovation support system	15	7.43%
	Public service	10	4.95%
	Infrastructure construction	18	8.91%
	Science and technology information support	7	3.46%
	Talent cultivation	23	11.39%
	Capital investment	18	8.91%
Environmental side	Strategic measures	3	1.49%
	Finance support	5	2.48%
	Goal setting	29	14.36%
	Policy support	5	2.48%
	Intellectual property	8	3.96%
	System construction	5	2.48%
	Organization management	6	2.98%
Demand side	Research cooperation	14	6.93%
	Trial project	23	11.39%
	Information communications	13	6.44%

Table 5. Distribution of dimension of policy stakeholders

Policy subject	Regulators dimension	Providers dimension	Demanders dimension
Frequency	118	55	29
(Percentage)	(58.41%)	(27.23%)	(14.36%)

4.3. X-Y dimension of China's AI policies

We categorized 202 policies to the matrix framework (**Table 6**) to show the distribution of 16 groups of AI policy instruments among the three types of stakeholders. This matrix framework, which adopts the X-Y dimension, focuses on policy instruments from the stakeholder perspective. As previously mentioned, we classified stakeholders into three dimensions, and the distribution of the 16 types of policy instruments used by them is shown in Table 6. In terms of the demand side, "trial project" emphasizes the government and universities, accounting for 13 and 10, respectively, but none of the items are in the demanders dimension. The largest of this set of policy instruments focuses on the providers dimension, which highlights the importance of universities and research institutions. On the environmental side, there is more attention on the government, especially in "goal planning" with 29 items in the regulators dimension. It is obvious that the largest proportion of

Table 6. Distribution of policy instruments related to policy stakeholders

Policy instrument	Elements of instrument	Regulators dimension	Providers dimension	Demanders dimension
Demand side	1. Information communication	4	3	6
	2. Trial project	13	10	0
	3. Research cooperation	1	10	3
Environmental side	4. Organization management	6	0	0
	5. Institutional construction	5	0	0
	6. Intellectual property	4	4	2
	7. Policy support	4	1	0
	8. Goal planning	29	1	0
	9. Financial support	2	1	2
Supply side	10. Strategic measures	2	1	0
	11. Capital investment	13	2	3
	12. Talent cultivation	9	12	2
	13. Technical information support	2	3	1
	14. Infrastructure construction	12	0	7
	15. Public service	7	0	2
	16. Industry support system	5	7	1

policy instruments is the "supply side", where "talent cultivation", which is related to the providers dimension, has 12 items.

5. Discussion

Overall, the initial construction of the AI policy system has been completed, and the 202 policy instruments are distributed evenly to a certain extent. As the results show, the development of AI relies on the social-economic environment; material and natural cultural environments; working, living, and social lifestyle environments; macroeconomic environment; and social microeconomic environment. Besides that, innovative development includes the providers and demanders dimensions, which are also the two main dimensions of policy stakeholders. We adopted deductive research here to ascertain whether the theory applies to specific instances (Hyde, 2000). Therefore, this section aimed to explore the potential explanation for the use of policy instruments and to discuss the understanding of the innovation ecosystem in universities based on the AQH model from the analysis of AI policy instruments and stakeholders in China.

5.1. AQH Model: Supply-side policy instruments

The Chinese government has attached great importance to the cultivation of AI talents and has proposed plans and strategies to establish cooperation with research institutions and universities. In general, the government attaches great importance to promoting the construction of an innovation ecosystem with AI innovation and development environment as the main body. Four hundred and forty universities have successfully applied for the AI undergraduate program as of 2022 (China's New-Generation Artificial Intelligence Technology Industry Development Report, 2022). AI talents play a key role in technology and information communications; hence, the national and provincial governments formulate policies of talent cultivation for the frontier industries. For example, G6-5 implicates that the main objectives and tasks are attracting and cultivating high-end, innovative, and entrepreneurial talents of AI; supporting the growth of leading and young top-notch talents; supporting the strengthening of professional construction of AI-related disciplines; and guiding the training of skilled talents urgently needed for industrial development. As the AQH model presents, universities have a key role in dynamic capabilities and the innovation ecosystem, and their role varies according to the policy instruments' impacts. In terms of the supply side, the Chinese government requires the Ministry of Education to regulate and invest in provincial departments of education. Thus, universities can use their dynamic capabilities to establish the innovation ecosystem during the evolutionary process (Feng et al., 2019), such as talents output and project input, to follow the government guidance and satisfy the requirements of industries.

5.2. AQH Model: Environmental-side policy instruments

The environmental-side policy instrument with the highest number is "goal setting", which is an essential step for policy implementation, in that it establishes the desired objectives and outcomes. In the AQH model, the environmental-side policy instruments can be understood as governmental strategies. In the policy of "The Construction of a National AI Innovation and Application Pilot Zone" (Beijing Municipal People's Government, 2021), the Chinese government guides research institutions and universities to follow relevant principles and laws when developing AI by studying the legislative works (Yang and Huang, 2022). These supportive policies may promote more discourse among universities when establishing the innovation ecosystem. Another element of the environmental side is "intellectual property". The way to promote the transfer and transformation of science and technology is to protect the intellectual property rights of scientific research institutions and technicians by encouraging universities, scientific research institutions, and technicians to transfer scientific and technological achievements to each other.

5.3. AQH Model: Demand-side policy instruments

The AQH model in this dimension proves that the scientific research cooperation policy promotes technological cooperation and innovation among economic entities by guiding institutions of higher learning, scientific research institutes, and other enterprises to carry out technical cooperation. Specifically, demand-side policy instruments include policies and measures such as encouraging enterprises to jointly apply for AI projects, promoting the flow of talents between different entities, and encouraging enterprises to form industry innovation strategic alliances. From the perspective of work content, it also includes implementing the reform of the management system of the right to use, benefit from, and dispose of various scientific and technological achievements, as well as adjusting the ownership of technological achievements, establishing income sharing and tax incentive systems, establishing a professional technology transfer service system, etc. Regarding Frank's (2009) "organizations-universities" integrating with the governance of AI policies, the roles of universities in the ecosystem clearly suggest the importance of dynamic capabilities. Because of this managerial capability in universities, internal talents and external resources can be integrated and reconfigured, which is conducive to the implementation of policies, based on the above analysis of China's AI policies.

5.4. Role of universities in innovation ecosystem—Policy instruments proposed by policy stakeholders

It is repeatedly mentioned that China's AI policies focus on the interaction with stakeholders of different dimensions, such as demanders (market) as well as providers (universities), to explore various collaborative innovation models, promote the integration of science and technology and industry, promote the transfer of science and technology, and then form an open and efficient technological innovation network. The focus of the policy, which is to promote interaction between the stakeholders, involves the integration of production, education, and research and the promotion of the transfer and transformation of scientific and technological achievements.

Providers and demanders are an indispensable part of the science and technology innovation policy system in China, and the same is true of AI policies. Regulators (government) have adopted a variety of science and technology policy measures to expand the group of technological innovation entities, further enhance the innovation capabilities of various market entities, and clarify various types of technological innovation. The functional positioning of the providers in the technological innovation system further activates the technological innovation vitality of the demanders. Providers and demanders in the field of science and technology entrepreneurship are quite diverse. For example, providers include colleges and universities, scientific research institutions, scientific and technological talents, as well as various technology incubation organizations and public technical service institutions. Demanders include small- and medium-sized enterprises and firms with business activities in different industries. First, enterprises are the core driving force in the technological innovation system. It has been proposed more than once, in China's development plans, to strengthen the dominant position of enterprises in technological innovation. Moreover, these enterprise-oriented, scientific, and technological innovation support policies encourage and drive enterprises to increase investment in innovative software and hardware facilities and equipment to enhance their independent innovation capabilities. Therefore, the policies and measures to stimulate the technological innovation of enterprises include guaranteeing enterprise research investment (supply side), supporting the establishment of enterprise research institutions (environmental side), guiding enterprise' technological entrepreneurship (supply side), and guiding the development and growth of high-tech small- and medium-sized enterprises (supply side). Second, colleges and universities, scientific research institutes, and various high-tech private non-enterprise units are the main public research forces in the provider dimension (supply side). From the perspective of providers, universities play two important roles in AI development, which are the "provision of talent" and "the production of knowledge". This means the quality of education in universities should be highlighted, rather than only focusing on increasing the absolute number of students and experts. Therefore, we can see how the scientific research and entrepreneurship policy for such institutions has adopted measures, such as the promotion of institutional innovation, co-construction of talent teams, establishment of platform bases, sharing of public resources and facilities, preferential policies on government taxes and fees, and international exchanges and cooperation, to promote the development of higher education and scientific research institutes. Third, the policy related to talent cultivation is a key aspect of technological innovation capability. The key tasks of the national science and technology talent policy, at the current stage, are to cultivate technologically innovative talents, attract overseas talents, develop a high-tech talent team, and establish a high-quality technical leader and leadership team. Fourth, various incubator and service organizations include high-tech business incubators, university science and technology parks, SME service platforms, technology intermediary service organizations, and various innovation incubation carriers. Local governments encourage their standardized development by setting thresholds and giving correspondingly preferential tax and fee policies.

6. Conclusion

This research work explored the distributions of China's AI policies, using qualitative text analysis to illustrate the specificities of the AI innovation ecosystem in China's universities. First, it introduced the context of the application of AI in China and its emphasis on different aspects. Second, it synthetically reviewed the literature on the theory of dynamic capabilities and the innovation ecosystem. The deductive research commenced with these established theories and sought to ascertain whether the theory applies to specific instances (Hyde, 2000). Therefore, an AQH model was developed, drawing on the theory of dynamic capabilities and the innovation ecosystem. The AQH model was developed from the ATH model of Arenal et al., but it highlights the universities' roles, which differ from the other dimension shifts.

This research work utilized policy instruments and policy stakeholders as the matrix framework to analyze China's AI policy distribution and its characteristics. The overall result is a strong alignment of universities and government interests, with the ecosystem most developed in the areas of the supply, environmental, and demand sides, together with their supporting policies. However, most policies are collected on the supply and environmental sides, whereas the demand side has few policies. Moreover, the national government focuses on the integration of local advantageous innovation resources, based on the current regional conditions, to promote the development of AI. In terms of the Y dimension, the demanders dimension seems to be weak compared with the other two, presenting the imbalance of Y dimensions, although "talent cultivation" accounts for the most number in the providers dimension. Therefore, the government needs to further regulate and promote the stable development of mechanism construction by continuously establishing relevant guarantee mechanisms, such as strengthening organizational leadership, improving organizational security mechanisms, strengthening government support, implementing policy incentive mechanisms, improving quality assurance system, strengthening intellectual property protection, standardizing management services, improving trademark strategy service system, focusing on talent training, and improving trademark strategy implementation system. This will strengthen quality supervision and evaluation and consolidate the development foundation of relevant mechanisms.

However, there are some limitations to this study. First, the literature review should be more systematic and needs to further explain the mechanism of the implication of dynamic capabilities and the innovation ecosystem in China's universities. Second, this is a novel study, adopting detailed policy analysis, but the research method needs to be enlarged to a case study. Therefore, in the future, using dynamic capabilities, we will select two or three universities, as specific cases, to further explore how AI policies are applied to them, and how universities act as leaders in the innovation ecosystem. Third, the X-Y dimension for the policy analysis is not enough, and the policy analysis should be holistically invested and analyzed empirically. Therefore, it requires a further quantitative review to evaluate the distribution of AI policies. Despite these limitations, we can conclude that the AI ecosystem in China has a favorable context, and AI talents and governance are boosting the advance of the AI-enabled innovation ecosystem in China's universities. The three policy stakeholders are strongly related, and the dynamic interactions lead to a strong ecosystem.

Acknowledgements

This research is partially funded by JSPS KAKEN #22K13754.

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