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| RESEARCH ARTICLE

Analysis of Characteristics of Cooperation Network of Smart Agriculture Technology Companies: China as an Example

Ke Wang
School of Management, Shanghai University, Shanghai, China
Corresponding Author: Ke Wang, **E-mail**: jsxzkewang@163.com

| ABSTRACT
The development of new technology and the Internet has provided opportunities for the development of smart agriculture, but at present, the development of smart agriculture is still in the primary stage and faces many urgent technical problems, so most companies enhance their technological innovation capabilities through cooperation with other companies. This paper analyzes the characteristics of cooperation networks of smart agriculture technology companies and the differences in different stages by collecting companies with which smart agriculture technology companies have cooperation relationships and applying social network analysis. The results show that there are few cooperative relationships between smart agriculture technology companies, mostly with large information technology companies (e.g., Huawei and Alibaba), research institutes, and other non-agricultural companies. In the cooperation network, large information technology companies such as Huawei and Alibaba, China Agricultural University, Chinese Academy of Sciences, and Chinese Academy of Agricultural Sciences occupy important positions. However, the overall network density is low, and the cooperation is not tight enough, indicating that the development of smart agriculture technology companies needs to be improved. The findings of the study can provide suggestions for the development of smart agricultural technology companies.

| KEYWORDS

Smart agriculture, Cooperation network, Digitization

| ARTICLE INFORMATION

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1. Introduction

At present, the main task of innovation-driven development strategy is to improve the efficiency and effectiveness of traditional industries and traditional agriculture and to promote China's development to the middle and high-end levels in China. Along with the accelerated emergence of new technology such as the Internet, the Internet of Things, cloud computing, big data, and other technologies used in various aspects of agricultural production, digital agriculture, and smart agriculture have come into being. At present, the development of smart agriculture is still at the primary stage and has not formed the mainstream and scale, and the fragmentation of agricultural production is more serious. As a result, various smart agriculture technology companies have emerged to actively develop new agricultural technology and applications.

However, smart agriculture technology companies are currently facing fierce competition, with startups springing up and high homogenization of development content. How to maintain a competitive advantage in smart agriculture technology innovation and improve application feasibility is an important issue. This paper constructs a cooperation network of smart agriculture through the data of strategic cooperation and studies its basic characteristics, which can provide countermeasures and suggestions for the innovation-driven development of the smart agriculture industry in China.

2. Literature Review

In China, due to serious land fragmentation, small-scale farmers, low overall informationization level in rural areas, and weak R&D capability of core technologies, smart agriculture is facing serious challenges(Xiong, 2020). The development of smart agriculture involves not only agriculture itself but also various industries and requires multi-industry and cross-level joint deployment in order to the feasibility of achieving agriculture transformation. Therefore, some scholars explain smart agriculture from the perspective of economics and look for a breakthrough path, arguing that smart agriculture breaks the fetters of traditional industrial elements and realizes even multi-directional feedback of data and information. However, there are still problems, such as lack of highly qualified labor, difficulties in connecting with small farmers, and insufficient foundation for information construction, which need to be solved(Zhao, 2020). Some studies analyze the current situation and trends of smart agriculture technology development from patent data, pointing out that compared with foreign countries, China's smart agriculture is still in the initial stage of pilot demonstration and industrialization and needs to seize the opportunity of information technology development, improve the independent innovation capability of core technology, and increase policy support to cultivate a good ecological environment for smart agriculture technology innovation(Huang et al., 2021). Lv Xiaogang (2020)points out that digital agriculture has made certain achievements, rural network infrastructure construction capacity has been significantly improved, realizing the same network and speed development pattern with urban areas, basically reshaping the whole process of the agricultural and rural supply chain, increasing the market demand potential, the rapid development of rural e-commerce. Meanwhile, there are also challenges related to agricultural data and information resources sharing mechanisms to be further improved, the level of technological innovation is not high, and the core technology research and development capabilities are not strong. In response to these technical R&D capability issues and the current situation, such as innovation breakdowns, Sun Hongmin et al.(2020) study the specific application of blockchain-enabled IoT technology in smart agriculture, including smart agriculture system design, monitoring system, wireless sensor network subsystem, and wireless broadband network transmission system, which can be used for smart agriculture supervision, resource management, and refinement operations. At present, due to the lack of promotion and application of new technology, there are some problems such as inconsistent standards, etc. Yan Zhangpeng et al.(2013) propose an implementation plan for smart agriculture based on IoT technology, which focuses on building an agricultural IoT sensing and application technology system, promoting the R&D, integration, demonstration and promotion, and application of agricultural IoT technology, and strengthening resource integration.

This shows that the innovative breakthrough of smart agriculture technology is a problem that needs to be solved. The breakthrough and application of the core technology of smart agriculture require cooperation between different companies, research institutes, and other related institutions, of which companies are the main force. The development of smart agriculture companies cannot be separated from cooperation with related companies. The current research on smart agriculture is mostly focused on the overview of the development status, and there is less research on the cooperation between smart agriculture companies and related companies and even a lack of research on the analysis of cooperation networks.

Therefore, this study is dedicated to exploring the cooperation network characteristics of smart agriculture companies and proposing countermeasures and suggestions for the innovative cooperative development of smart agriculture companies so as to better realize the digital agriculture revolution and promote the development and application of smart agriculture technologies.

3. Methodology

3.1 Sample

At present, smart agriculture companies are mostly technology innovative enterprises, focusing on research and innovation of agricultural digital platforms, artificial intelligence, IOT inspection and monitoring technology, big data analysis technology, cultivation decision data platform, etc., and integrated use of remote sensing, GIS, Beidou satellite and other technologies. Therefore, the object of this study is smart agricultural technology companies. Since smart agricultural technology companies are mostly startups, there is little patent cooperation between companies and companies, and in order to build the innovation network of smart agricultural technology companies, the data sources are mainly companies with strategic partnerships with smart agriculture technology companies and the information of companies that have cooperation with smart agricultural technology companies is collected by checking the official websites of companies and crawling the whole Internet.

3.2 Procedure

The first collection was made with companies that had partnerships with smart agriculture technology companies that had already received investment. The second collection was made to expand smart agriculture companies to general start-ups. The results reveal that the partners are mostly information technology companies, universities, research institutes, governments, and multinational companies.

3.3 Cooperation Status

In the first stage of data collection, there are 45 smart agriculture technology companies that had received investment, and there are 178 partners cooperating with these 45 companies. In the second stage, there are 103 smart agriculture technology companies and 370 partners cooperating with them, as shown in Table 1.

Table 1: Number of smart agriculture companies and partners

	Smart agricultural technology companies	Partners
Stage 1	45	178
Stage 2	103	370

4. Cooperation network analysis

In this study, the edge table and the table of nodes of the cooperation network are constructed by sorting out the partners of smart agriculture companies, and the cooperation network diagram is drawn using Gephi. The nodes in the network diagram indicate companies and partners, and the edges connecting the nodes indicate the existence of a cooperative relationship between two partners.

4.1 Stage 1 Cooperation Network Analysis

The first stage cooperation network involves 45 nodes of smart agriculture companies, among which the companies with higher node centrality are XAIRCRAFT, Shengu, TalentCloud Information, KEBAI SCIENCES, Jiahe Technology, MCFLY, Aikenong, Yulintu, Nongbo, TopXGun, etc. The partners involve 178 nodes, among which the partners with higher node centrality are Huawei, Alibaba, the Chinese Academy of Sciences, and other units. It can be seen that on the road of smart agriculture development, Huawei and Alibaba, such large information technology companies, can provide a greater thrust.

4.2 Stage 2 Cooperation Network Analysis

In the second stage, the cooperation network involves 103 nodes of smart agriculture companies, among which the companies with higher node centrality include XAIRCRAFT, Shengu, TalentCloud Information, KEBAI SCIENCES, Jiahe Technology, MCFLY, Nxin, Byaero, AIOTAGRO, and Bangbo, etc. The partners involve 370 nodes, among which the nodes with higher centrality are Huawei, Alibaba, Chinese Academy of Sciences, China Agricultural University, and Chinese Academy of Agricultural Sciences. Huawei and Alibaba still occupy this dominant position, indicating that the digital transformation of agriculture is an inevitable trend, and giant companies have taken the digital agriculture layout.

4.3 Comparative analysis of the characteristics of the two-stage cooperation network

In order to compare the characteristics of the cooperation network in two stages, the top 10 smart agriculture technology companies and the top 10 partners in terms of centrality are selected, as shown in Table 2.

Table 2: Basic information of two-stage network nodes

	Smart agriculture technology companies	centrality	Partners	centrality
Stage1	XAIRCRAFT	20	Huawei	12
	KEBAI SCIENCES	18	Chinese Academy of Sciences	7
	Shengu	16	Alibaba	6
	TalentCloud Information	14	China Mobile	5
	TopXGun	14	JD	4
	Yulintu	13	China Agricultural University	4
	Aikenong	12	Chinese Academy of Agricultural Sciences	4
	Hoire	12	South China Agricultural University	3
	Jiahe Technology	12	China Unicom	3
	ZUOANXINHUI	12	ANT GROUP	2
Stage2	AIOTAGRO	30	Huawei	16
	Bangbo	27	China Agricultural University	13
	Yunshangagri	23	Alibaba	12
	XAIRCRAFT	20	China Mobile	10
	KEBAI SCIENCES	18	Chinese Academy of Agricultural Sciences	10
	Nxin	16	China Telecom	9
	Shengu	16	China Unicom	9

Byaero	16	Chinese Academy of Sciences	9
Sowreap	16	Hikvision	6
BEBT	15	JD	6

The results show that in the first stage cooperation network (invested smart agriculture technology companies), the top-ranked smart agriculture technology companies include XAIRCRAFT, KEBAI SCIENCES, Shengu, etc. In the second stage cooperation network (invested and general smart agriculture technology companies), the top-ranked agriculture technology companies include AIOTAGRO, Bangbo, and Yunshangagri. The top-ranked companies in the first stage are XAIRCRAFT and KEBAI SCIENCES, which are ranked 4th and 5th; indicating that smart agriculture technology companies cannot rely on themselves for long-term development and must seek wider cooperation and that general companies need to strengthen cooperation more urgently. Moreover, the top-ranked partners in the first stage are Huawei, Chinese Academy of Sciences, Alibaba, China Agricultural University, and Chinese Academy of Agricultural Sciences; the top-ranked partners in the second stage are Huawei, China Agricultural University, Alibaba, Mobile, and Chinese Academy of Agricultural Sciences. In the two cooperation networks, these partners occupy an important position, which shows that the development of smart agriculture technology companies needs to cooperate with large information technology companies and authoritative research institutions and colleges so as to seek technical breakthroughs.

Table 3: Two-stage network characteristics

	Nodes	Number of network connections	Network Density	Network Diameter	Average path length
Stage1	225	227	0.009	8	4.503
Stage2	473	514	0.005	3	1.061

Through the comparative analysis of the two stages (as shown in Table 3), the number of nodes expands from 225 to 473, and the number of relationships between nodes also increases from 227 to 514, which shows that the scale of the cooperation network expands, but the difference between the cooperation network of smart agricultural technology ecompanies in the two stages is not significant, and it was only the increase in the number of companies that increases the number of relationships between nodes, and the number of relationships does not produce a substantial increase due to the increase of companies. It can be shown that there is little cooperation between smart agriculture technology companies, and most of them have cooperative relationships with other non-agricultural companies.

The average path length of the first stage cooperation network is 4.503, and the network diameter is 8. The average path length of the second stage cooperation network is 1.061, and the network diameter is 3. Compared with the first stage, the network diameter and the average path length in the second stage have been reduced substantially, which indicates that the addition of general smart agriculture technology companies has improved the transmission performance and efficiency of the network. The density of the cooperation network in both phases is low, indicating that the tightness of cooperation between companies is low.

5. Conclusion

This study applies the social network analysis method to analyze the cooperation network of smart agriculture technology companies and analyzes the characteristics and differences between the two stages of cooperation networks. The results show:-

- At present, there are few partnerships between smart agricultural technology companies, mostly cooperating with large information technology companies (e.g., Huawei, Alibaba), research institutes, and other non-agricultural companies.
- Huawei, Alibaba, and other large information technology companies, China Agricultural University, the Chinese Academy of Sciences, and the Chinese Academy of Agricultural Sciences occupy an important position in the cooperation network. In the process of digital transformation of agriculture and the development of smart agriculture technology companies, the technical support of giant companies and the contribution of knowledge from authoritative research institutions are indispensable.
- At present, the overall network density is low, and the cooperation is not tight enough. The development of smart agriculture technology companies is still in the primary stage and needs to be improved. This requires intensified cooperation among companies to jointly break through the core technology.

The current lack of cooperation among smart agriculture companies has caused a waste of knowledge to a certain extent. It is necessary to strengthen cooperation among companies, which is more conducive to achieving breakthroughs and innovations in core technologies. At the same time, cooperation among smart agriculture companies is conducive to the unification of technical standards and compatibility of digital platforms to avoid technical overlap, which is more conducive to the application of technology. Moreover, smart agriculture technology companies should continue to maintain cooperation with giant information technology companies and research institutes to better realize the sharing and flow of knowledge.

There are still some limitations in our study. For example, the sample size could be further increased, and only China was used as the study sample. Future studies need to include various countries as a research sample.

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