Main Constraints in the Agricultural Technological Innovation in China

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Tiivistelmä – Referat – Abstract

The research question of this thesis focuses on what the main constraints in the agricultural technological innovation in China are. The primary aim is to identity the most serious constraints/predicaments in Chinese agricultural technological innovation, and the most possible/main reasons behind those constraints. Based on the research findings, recommendations for some viable countermeasures and a way out of this bind could be provided for relevant policymakers in the Chinese agricultural sector.

This thesis adopted a qualitative analysis based on grounded theory. The objects of analysis/data were 20 articles in Chinese academia selected according to these criteria: high relevance of titles and keywords to the thesis' purposes; high representativeness of contents that relate to the thesis' research questions; highly informative articles; high citation rates and influences of the articles.

According to the study's findings, there are four major constraints to the advancement of agricultural science and technology innovation: 1) severe lack of financial investment in agricultural research; 2) low rate of conversion of agricultural science and technology achievements; 3) sluggish agricultural technology promotion and diffusion system; and 4) insufficient innovation capacity of scientific research actors, as well as a lack of collaborative innovation among them.

This study fills a gap in the literature by conducting a systematic and comprehensive analysis of the barriers to agricultural science and technology innovation in China. The Chinese Ministry of Agriculture should implement deliberate policies and initiatives to promote agricultural innovation in China. Quantitative analysis could be used in future studies to obtain more accurate analysis results.

Avainsanat – Nyckelord – Keywords
Constraints; Agricultural Technological Innovation; China

Ohjaaja tai ohjaajat – Handledare – Supervisor or supervisors
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1 Introduction

1.1 General background

China is a huge agricultural country with a significantly important position of grain production and consumption in the world (Veek et al., 2020). The Chinese agricultural economy growth is closely related to the progress of agricultural science and technology, and it is reported that the contribution rate of agricultural science and technological progress rose to 57.5% in 2017 in China (CGTN, 2018). However, the Chinese agricultural sector is still facing challenges in relatively low agricultural productivity, especially labor productivity, smallholder farmers' low incomes, and lack of international competitiveness in the quality of agricultural product. Moreover, environmental problems nowadays in China increased with the increasing intensity of land and water resource use, which have caused arable land loss, degradation of water quality and availability, and climate change (Veek et al., 2020; Veek and Shui, 2011), given the fact that China uses only 6% of fresh water and 7% of arable land in the world for feeding nearly 20% of global population (Wong and Chan, 2016).

To foster a long-term sustainable agricultural development and to ensure the effective supply of agricultural products, the fundamental way out lies in science and technology. As indicated by UNCTAD (2017), agricultural scientific and technical applications may play an essential role in addressing the various aspects of sustainable food system, such as food security through improving agricultural productivity, climate change mitigation and adaptation through information and knowledge transfer, adapting food production to climate change, and precision agriculture. In the context of Chinese agriculture sector, Fuglie and Rada (2018) indicated that aggregate total factor productivity in China’s agriculture, forestry and fishery sector as a whole grew smoothly at an annual growth rate of 3% during 1978-2015, i.e. the post-reform period in China, accounting for 61.4% of output growth, which was attributed to technological progress and increased public R&D investment. Likewise, Sheng et al. (2019) also have shown that the average total factor productivity growth in agricultural sector in China during 1978-2016 was 1.9%, accounting for proximate 40% of agricultural output growth. Additionally, the contribution of technological progress to agricultural economic growth in China has been indicated to surpass the role of agricultural labor, land, fertilizers, pesticides and other factors input, and had become the main driving force for agricultural economic growth in China (Sheng et al., 2019). Chinese agricultural economic growth has shifted from relying on the increase of primary factor inputs such as labor, land and energy, to relying on scientific and technological innovation (Zhao et al., 2018). Therefore, for the Chinese agricultural sector, it is necessary to place agricultural science and technology in a more prominent position, via breaking through the obstacles of science and technology innovation mechanism and the greatly increasing

investment in agricultural science and technology, in order to achieve a strong impetus for agricultural production, farmers' income, and rural prosperity.

It is well known that China central government has attached great importance to the development of agricultural science and technology and the promotion of technology innovation. Since 2004, the Central Committee of the Communist Party of China (CPC) and the State Council has issued No. 1 Central Documents that focus on "agriculture, rural areas and farmers" for 18 consecutive years. Especially in 2012, 2016, and 2017, the state issued the 2012 No. 1 Central Document "Opinions of the CPC Central Committee and the State Council on accelerating the advancement of agricultural science and technology innovation and continuously enhancing the supply capacity of agricultural products", the 2016 No. 1 Central Document 'establishing innovation as one of the most important policy agendas in agriculture', and the 2017 No. 1 Central Document 'strengthening basic research in agricultural R&D and enhancing innovation capacity through constructing national agricultural high-technology development zones and promoting public and private partnerships' (OECD, 2018). In addition, other agricultural policy guidance documents issued by the Ministry of Agriculture, the National Development and Reform Commission, the Ministry of Water Resources and other multiple ministries and commissions also clearly required the promotion of agricultural technology innovation. In 2000, China launched the world's largest and most decentralized public agricultural R&D system, and public investment in agricultural R&D has quadrupled during 2000-2013 in China (Sheng et al., 2019).

Although agricultural science and technology progress has significantly contributed to agricultural economic growth in China, questions remain, e.g. According to China agricultural sector development report 2020 (2021), the relative lack of funding is a significant cause of the failure to break through the bottleneck in agricultural science and technology progress. Likewise, according to the empirical findings, the development of rural finance has a considerable positive effect on the development of agricultural technology innovation (Liu et al., 2021). In addition, China's traditional government-sponsored agricultural technology extension system and promotion model cannot completely meet the requirements for agricultural development in the new era. This situation could result in delayed information, unreasonable investment structure of innovative technology promotion funds, and lack of agricultural extension professionals in the agricultural extension system at local, regional and national levels (HU et al., 2009; OECD, 2018). Given the fact that such problems have not been effectively resolved yet, it is argued that building an innovative agricultural science and technology extension service model in the new period is an urgent issue in China.

There are plentiful studies on the main constraints in Chinese agricultural technological innovation in Chinese academia, however, to my knowledge, not so many studies on it have been published internationally based on my search of the international database. Thus, to fill this gap, the motivation in my study is to do a synthetic review on what main constraints in Chinese agricultural technological innovation have been presented in Chinese academia through a comprehensive literature review for the relevant publications in Chinese during 2012-2019, to find out what main reasons behind these obstacles, and then to further identify the categories of those constraints. Based on the previous research results of other researchers, this study will provide possibly useful information for the development of Chinese agricultural technological innovation and provide the possible research focus on how to overcome the obstacles to agricultural technological innovation.

1.2 Study objectives

This study aims to identify and classify the current main problems that exist in the scientific and technological innovation in the Chinese agricultural sector. Specifically, the research objectives mainly focus on 1) Identification of the most serious constraints and predicaments in agricultural technological innovation; 2) Identification of the main/most possible reasons behind those constraints and predicaments; 3) Identification of implication and recommendations of some viable countermeasures and way out of such dilemma for relevant policy decision-makers in the Chinese agricultural sector.

2 Theoretical background

2.1 Promotion of agricultural technological innovation and its related concepts

Agricultural technology innovation in a narrow sense refers to the invention of new agricultural technologies achievements. In a broad sense, it is a series of behaviors that introduce new animal and plant varieties or production methods into agricultural economic activities to realize the recombination of agricultural production factors and the improvement of production efficiency. It mainly composes of a series of related comprehensive activities including scientific, technological, organizational, commercial and financial process such as research and development, experimentation, promotion, application and diffusion of new varieties, new technologies and new methods in agricultural production and management (Anandajayasekeram, 2011).

Agricultural technological extension/promotion refers to the overall process of applying relevant scientific and technological achievements and practical technologies to the entire process of agricultural production through experiments, demonstrations, training, guidance, and consulting

services. The main purpose of agricultural technology extension/promotion is to provide farmers and enterprises with technical information and service, to enhance effectively adopting these new technologies in agricultural production. Van Beek (1997) advocated for a stronger connection between technological innovation and technology promotion. Similarly, Röling (1996) proposed to increase the effectiveness of extension by developing a system of agricultural science knowledge and strengthening the link between innovation and extension. Moreover, Van Crowder and Anderson (1997) emphasized the importance of regarding research, extension, and education as interconnected and integral components of an integrated agricultural technology system, as well as the need to develop policies to facilitate structural and functional linkages among them.

Agricultural technology diffusion refers to the process in which agricultural technology is widely adopted by farmers in a larger area. The diffusion is conducive to accelerating the transformation of agricultural scientific and technological achievements into agricultural production and development (Mcgrath & Zell, 2001). By doing so, the value of technological achievements is realized through technology diffusion, thereby increasing agricultural productivity, vice versa, increased productivity facilitates further innovation of agricultural technology.

2.2 Features of agricultural technological innovation

Public goods characteristics with positive externalities

Agricultural technological innovation is particularly hard to be fulfilled solely by the private sector through the market function. Instead, it mostly depends on the direct intervention by the governments and public sector. Meanwhile, with public goods characteristics, agricultural technological innovation has positive externalities and spill-over effects to firms and consumers, and it mainly manifests in not only economic benefits of agriculture, but also environmental benefits of protecting ecology and social benefits related to food security (Liu et al., 2021).

Complexity and uncertainty

Agricultural technological innovation is subject to the natural conditions of agricultural production and the laws of biological production (Klerkx, Aarts & Leeuwis, 2010). Thus, the promotion and application of various agricultural technological innovations must be matched with corresponding natural and social economic conditions.

Periodicity

Periodicity of agricultural technological innovation, on one hand, refers to the time course of a technology system from generation to application, and then to the emergence of new technology and its elimination. On the other hand, it refers to the process of transforming science and technology into productivity accompanied with economic benefits. In contemporary society with competitive market, the renewal of agricultural technology has accelerated and the whole cycle has been significantly shortened (Huang & Liu, 2009).

Approaches

(1) Through improving the level of agricultural mechanization, i.e. modern and advanced agricultural machinery, transportation tools, facilities, etc., thus improving the capacity and efficiency of laborers force for agricultural production (Klerkx et al., 2012).

(2) Through improving the level of agricultural biotechnology to increase the production performance of agricultural animal and plant varieties, meanwhile, enhancing the quality of agricultural products to meet the different needs of people's production and lives.

(3) Through improving the management methods and means of agricultural production and operation so as to increasing the utilization efficiency of agricultural production resources for high agricultural economic benefits.

2.3 Principal forces of agricultural technological innovation

Regarding principal forces for agricultural technology innovation, they are composed of a broad range of direct and indirect important actors: government, scientific research institutions, colleges and universities, agriculture-related enterprises, other agribusinesses, intermediate organizations, extension and service institutions, family farms, and famer cooperatives (OECD, 2018). Their respective status and functions vary greatly. Farmers are the beneficiaries of the innovation process and the actual users of technology. Generally, they do not participate in technological innovation directly, but they are the principal part to test the effect of innovation (Biggs & Clay, 1981). Colleges, universities and scientific research institutions are the source of technological innovation. They not only provide theoretical knowledge, but also provide society with a large amount of agricultural innovation knowledge and professionals with relevant expertise through education and training. Intermediary agencies are the lubricant of technological innovation. As the link and bridge between the technology supply and demand sides, their existence helps to accelerate the promotion, diffusion and application of new technologies.

2.3.1 Enterprises as one of principal forces in developing agricultural science and technology (S&T) innovation

Agricultural enterprises are important forces for agricultural S&T innovation. Agricultural enterprises in China mainly invest in agricultural innovation activities with high market return on investment, e.g. favoring food processing, agricultural chemical inputs, farming machinery, hybrid seeds and genetically modified crops breeding (OECD, 2018). Private investment takes the form of investment by enterprises, financial institutions and venture capital. In recent years, the Chinese central government has begun to strengthen the dominant position of enterprises in agricultural S&T innovation, and vigorously promote collaborative innovation. Relevant survey found that the current models of S&T innovation in China's agricultural enterprises mainly include independent innovation, collaborative innovation and imitative innovation, which is determined by the technical reserves and business capacity of agricultural enterprises (Nian-hong, C., 2010).

2.3.2 The government research and development (R&D) investment in agricultural technological innovation

In China, the governments are the key leaders and organizers of agricultural technological innovation, which play the major role in system supplier, policy maker, and environmental builder (OECD, 2018). Most importantly, the governments have been the dominating investors (OECD, 2018).

The ratio of R&D expenditure to GDP effectively measures the intensity of science and technology investment in a country or region, while the scale of S&T innovation activities illustrates the ability of sustainable development. It is argued that in the world economic activities, reaching R&D investment at 3% could basically meet the needs of enterprise's R&D; only when the R&D investment reaches or exceeds 5%, can the development of technology reach the level of international competition and can innovative products be competitive globally (Pardey et al., 2016).

In terms of the impact of government R&D investment on innovation efficiency, there are two views in academia: One says that government R&D investments promote the improvement of innovation efficiency and have a "leverage effect" (Lach, 2002; Czarnitzki & Hussinger, 2004). Government R&D investments not only reduce costs and risks of enterprise technological innovation, but also can stimulate the motivation of enterprises to more R&D. In short, this view claims the positive influence on innovation efficiency. Another view is that government R&D investments are not conducive to the improvement of innovation efficiency, instead, have a "crowding-out effect" (Görg & Strobl, 2007). The investment efficiency of enterprises is higher than that of government; government R&D investments will increase the demand for R&D resources of enterprises. When the supply of R&D

resources is inelastic, the investment of enterprises will be crowded out, thereby reducing the efficiency of innovation. According to a study conducted by Hu et al. (2011)., “public investments in technology development crowded out private R&D investment”.

3 Data and Methodology

3.1 Data

First, an exploratory search in the China Academic Journals Full-text Database of China National Knowledge Infrastructure (CNKI) is employed to collect peer-reviewed publications relating to agricultural technology innovation in China. The search results show 6655 relevant articles in total during 2012-2019 (see Table 1). Particularly the publications in 2012 is found to double or triple in size, compared to that in other years, the reason is assumed that Chinese authorities issued their first policy document of 2012 (No. 1 Central Document), underscoring the guidance of ‘accelerating the scientific and technological innovation to strengthen supply of agricultural products’ (FAO, date of the text, 01.02.2012).

Secondly, a primarily purposive selection of 120 articles (about 1.8%) is adopted. The selection standards are followed by 1) the citation rates, 2) titles of articles in relation to problems with and solutions for promoting agricultural technological innovations, 3) key words including difficult situation, predicament, constraint, or barrier for agricultural technological innovation, countermeasures, way out, path choice, or solution for technological innovation, agricultural technology extension and diffusion system, transformation of agricultural science and technology, incentive system in innovation, capacity in agricultural technological innovation, innovation efficiency, and demonstration zone of agricultural hi-tech industries, and 4) the relevance of contents of abstracts.

Thirdly, among 120 articles based on the above-mentioned selection standards, at last 20 targeted publications is used to in the thesis through content analysis.

Table 1: Results of the exploratory search, the primarily purposive selection, and the finally targeted of relevant articles

Year	Total number of relevant articles through extensive search	The number of the selected articles through selection standards	The number of the finally targeted articles to be used in the thesis through the content analysis
2019	462	5	1
2018	630	13	2

2017	703	16	3
2016	750	14	2
2015	708	17	3
2014	660	15	3
2013	935	16	2
2012	1807	24	4
Total	6655	120	20

3.2 Methodology

This paper adopts a systematic review and content analysis as the main methods to achieve research goal. The research is designed into three stages: primary systematic review of appropriate selections; purposive selection of most important literatures for content analysis to find out main constraints in agricultural technological innovation presented in the selected literatures; and analysis and conceptualization, i.e. generalization phase. The approach is considered as a theory-building exercise (Eisenhardt and Graebner, 2007; Dicecca, R, et al., 2016). A flowchart of the designed research process is presented in Fig. 1.

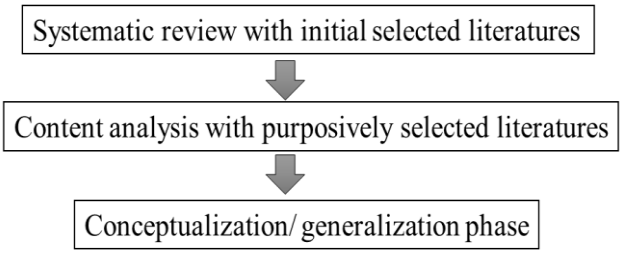

Fig 1. Designed research process

In order to properly use a theory- building exercise, I consider each selected literature as an analytical unit, which is based on their research questions relating to the constraints of agricultural technological innovation in China. Specifically, a systematic review of selected literatures will be applied to inductively analyze and conceptualize the restricting factors of agricultural technological innovation. Systematic review is a comprehensive and structured methodology to acquire and select relevant theoretical perspectives and practices in the most important literature in a certain field (Walker, Touboulic, & Alexander, 2015).

Content analysis has evolved in the treatment of textual data, recording counts to measure the observed frequency of pre-identified targets in social science research (Kleinheksel et al., 2020). Its applications of manifest analysis seek to identify observable targets within text, e.g. the number of instances a certain word appear in newspaper articles, and the number of times a target (i.e. code) appears within the text is used as a way to understand its prevalence (Kleinheksel et al., 2020). When

I use content analysis for the targeted literatures, codes relating to agricultural technological innovation will be short and descriptive words or phrases, or short sentences. The study can be identified an implementing of a theory-building exercise via content analysis (Eisenhardt & Graebner, 2007; Dicecca, R, et al., 2016), because it helps to develop a conceptual framework, which identify the main constraints of agriculture technological innovation, and supports a deeper understanding of the phenomenon being studied (Eisenhardt, 1989) and helps to conceptualize the analysis from a synthetic point of view.

The content analysis adopted in this thesis is based on grounded theory. As a social science research method developed by Glaser at the University of Chicago and Strauss at Columbia University. Grounded theory is a qualitative research method that frequently used to solve many microscopic problems in the field of sociology and is a scientific method for theory construction (Glaser & Strauss, 2017). This method is distinguished by the fact that there are generally no theoretical assumptions made before the research begins, but with the research questions, it begins directly from the actual observation and summarizes the concepts and categories from the primary data, i.e., it looks for the core concepts reflecting the essence of the phenomenon based on the systematic collection of data, and then rises based on the findings. It is a method of developing a substantive theory from the ground up by starting with a field to be studied and then sprouting concepts, categories, and theories from that field (Strauss & Corbin, 1997).

Grounded theory is a new theoretical paradigm that differs from the traditional deductive research method used by most scholars. The main feature of grounded theory is that it extracts new concepts and ideas from empirical facts, which is essentially a process of comparing, thinking, analyzing, and transforming information into concepts in order to build a theory. The reason why grounded theory is a novel theoretical paradigm is that it departs from the deductive approach of proposing ideas and then arguing them, which is common in traditional theoretical research. Instead, it focuses on discovery rather than verification (Allan, 2003). Figure 2 depicts the general process of grounded theory research.

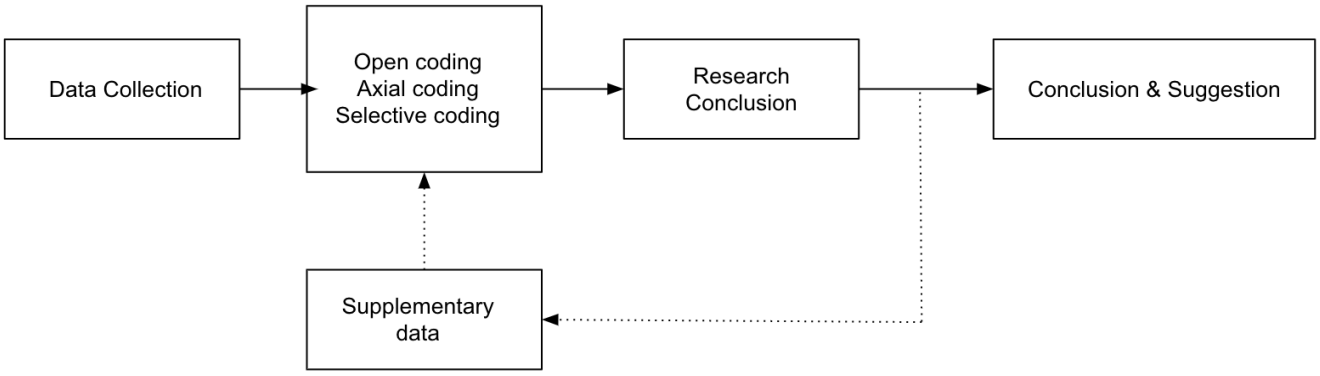

Fig 2. The general process of grounded theory

These characteristics of grounded theory are well suited to exploratory studies such as this thesis, which can avoid the "programmatic" limitations of empirical concepts or preconceived theoretical models in the empirical paradigm on the scope of the information used and the conclusions obtained.

The final samples of 20 articles are selected from the China Academic Journals Full-text Database of China National Knowledge Infrastructure (CNKI) for conducting content analysis (see Table 2), and they are determined by using the specific selection criteria as follows:

1) The title and keywords are highly relevant to the study's purpose and are consistent with the study's purpose.
2) The articles were highly representative of the specific content and closely relate to the research questions.
3) The articles give a wealth of information.
4) The articles have high citation rates and influence.

Table 2: 20 targeted articles for conducting content analysis

Year of publication	**The number of targeted articles**	**Titles of targeted articles**
2019	1	Research on the problems and countermeasures of China's agricultural science and technology innovation
2018	2	Review on Agricultural Technology Innovation Diffusion in China
		The Realistic Dilemma and Path Choice of Accelerating Agricultural Science and Technology Innovation in the Perspective of Rural Revitalization
2017	3	Present Situation, Problems and Countermeasures of Agricultural Scientific and Technological Innovation in China
		Discussions on the Transformation Efficiency of Agricultural Scientific Research Achievements

Year of publication	The number of targeted articles	Titles of targeted articles
		Problems and countermeasures of agricultural science and technology innovation in the process of modernization of China's agriculture
2016	2	Challenges of China’s Agricultural Scientific and Technological Innovation and Its Prospect During 13th Five-Year Plan Period
		Factors influencing the mechanism of agricultural science and technology innovation dynamics and innovation
2015	3	Characteristics, problems, and optimized paths of the construction of China’s modern agricultural science and technology innovation system
		Characteristics, Problems and Countermeasures of Agricultural Scientific and Technical Achievements Transformation in China
		The Mode, Risk, Problems and Countermeasures of Agricultural Enterprise’s Scientific and Technological Innovation
2014	3	Problems Existing in Transformation of Scientific and Technological Achievements in China’s Agriculture and Countermeasures
		A Study on Science and Technology Innovation of the Leading Enterprises of Agricultural Industrialization —Evidence from Anhui Province
		The Study on Fiscal and Financial Support to Agricultural Science and Technology Innovation
2013	2	Research on the Problems and Countermeasures of Agricultural Intellectual Property Protection in China
		Analysis of the Restrict Elements in the Development of China’s Agricultural Science and Technology Venture Investment
2012	4	Countermeasures on the Promotion of China's Agricultural Science and Technology Original Innovation Capability
		How can we speed up agricultural science and technology innovation
		Analysis of demand and supply factors that constrain agricultural science and technology innovation
		Current problems and suggestions facing agricultural science and technology innovation
Total	20	

4 Findings

The qualitative analysis of the collected data based on grounded theory employs three key steps: open coding, axial coding, and selective coding (Moghaddam, 2006). According to Saldaña (2012), code is: “a short word or phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data”. To obtain the theoretical

dimensions of the study in a more comprehensive manner, the qualitative analysis process necessitates continuous concept formation and dimension extraction of the data via a continuous cycle of data collection - concept formation - integration and reorganization - theory extraction. Simultaneously, in order to ensure the conclusion's comprehensiveness, reliability, and validity, new concepts discovered in subsequent collected data must be checked or combined with previously established concepts, any new concepts or categories must be revised until no new categories or categorizations appear, and so on repeatedly, until no new categories or categorizations appear, that is, theoretical saturation is reached. This paper follows the qualitative analysis method of grounded theory, and the basic study process is as follows:

Reliability test

The main task in grounded theory is to categorize the sample content into specific categories. In order to avoid individual bias from affecting the content coding process, the stability and accuracy of the coding needs to be tested (Potter & Levine-Donnerstein, 1999). When I use the analytic results obtained from open coding to test other textual contents, the coded contents can cover all the analyzed contents, which proves that the analysis results are saturated and guarantee the basic reliability.

Open coding: extracting concepts and categories

Open coding refers to the process of decomposing, comparing, conceptualizing, and categorizing the collected information at the start of the analysis, that is, an operationalization process of breaking up a large volume of information based on certain principles, assigning definitions to it, and then reassembling it in a new way. Its goal is to find the same or similar types in the collected primary sources while also naming the types in order to determine the concept and dimensions of the types (LaRossa, 2005).

There are three stages to open coding: 1) conceptualization, which involves extracting the contents from primary sources, breaking them down into independent sentences, extracting coding elements from these sentences, and then transforming from generalized to refined language to form preliminary concepts; 2) concept classification, which involves optimizing, analyzing, and filtering concepts and grouping concepts of the same genus together, and forming concept clusters belonging to the same category; 3) categorization, to further abstract and name the concept clusters. To generate initial concepts and discover conceptual categories from the original material, I will code and label the material sentence by sentence, without any authorial preconceptions or biases in the process. Table 3 displays the results of the open coding.

Table 3: Result of open coding

Example of coding content/data	**Categories to which open codes belong**	**Frequency**
Poor information circulation channels for scientific research results	Poor information circulation channels for scientific research results	3
Poor matching between scientific research results and market demand. The relatively high proportion of S&T activities in scientific research institutions and universities, and the low proportion in enterprises, makes the scientific research results as a whole more limited to academic factors, ignoring market demand	Mismatch between scientific research results and market demand	5
The transformation rate of agricultural S&T achievements is not high. Although some fields of agricultural S&T in China are at the forefront of the world, there is still the problem of low transformation rate of agricultural S&T achievements.	Low conversion rate of scientific research results	7
The transformation of agricultural research results and extension service system is inadequate.	Inadequate scientific research results transformation and promotion service system	6
The mechanism of international exchange and cooperation in agricultural S&T innovation is not yet complete.	Unsound international exchange and cooperation mechanism	1
Low degree of agricultural industrialization and difficulty in technology diffusion.	Low degree of agricultural industrialization	1
The university leans toward research and education and has no obligation to promote agricultural S&T	Lack of agricultural S&T extension by universities	1
The main position of enterprises is not strong, heavily dependent on scientific research units.	The main position of enterprises in scientific research is weak	4
There is a lack of major original achievements; some key areas have not yet broken through, especially those that can be truly applied to production practice, and there are fewer major breakthrough achievements with independent intellectual property rights.	Low capacity for S&T innovation	8
The interface between industry, academia and research of S&T innovation system needs to be strengthened.	The interface between industry, academia and research of the innovation system is untight	1
The total investment in agricultural S&T research is insufficient. As a public welfare and basic industry, the investment in scientific research in agriculture is very disproportionate to its basic status and has not been duly reflected in the public finance expenditure.	Insufficient funding for agricultural scientific research	9

Example of coding content/data	Categories to which open codes belong	Frequency
Low level of agricultural basic S&T resource allocation.	Low level of agricultural basic S&T resource allocation	1
Lack of incentive mechanism and risk compensation mechanism for agricultural S&T innovation.	Lack of risk compensation mechanism	2
Mismatch between the supply of financial products and actual demand.	Mismatch between financial product supply and actual demand	2
Narrow financing channels for agricultural S&T innovation.	Few financing channels for S&T innovation	1
The loss of agricultural research team and the serious lack of talents.	Lack of scientific research talents	4
Inadequate reward and evaluation mechanism for scientific researchers.	Inadequate evaluation mechanism of scientific research awards	4
Low comprehensive quality of the application subjects of agricultural S&T achievements.	Low comprehensive quality of agricultural actors	1
Inadequate laws and regulations, insufficient policy guidance	Insufficient guidance of agricultural S&T policies	1
Weak awareness of agricultural intellectual property (IP) protection	Weak awareness of agricultural intellectual property protection	2
Insufficient incentives for agricultural IP	Insufficient incentives for agricultural IP	1
Lack of financial guarantee for the construction of agricultural IP incentive system	Lack of financial security for agricultural IP incentives	1
Unclearly defined agricultural IP rights	Unclearly defined agricultural IP rights	1
Innovation system construction lags behind	Innovation system construction lags behind	1
The implementation cycle of agricultural research projects is considered too short	Short implementation cycle for scientific research projects	2
Agricultural S&T is organized in a lax manner, making it difficult to produce big results	The organization of scientific research is backward	2
Nodal funding management is not adapted to the requirements of agricultural research	Inadequate management mechanism of agricultural research	7
The conversion rate of S&T achievements varies widely among agricultural research institutions in different regions	Large differences in the conversion rate of results from agricultural research institutions between regions	1

Example of coding content/data	Categories to which open codes belong	Frequency
Market transactions for the transformation of our agricultural science and technology achievements are also inactive.	Inactive market transactions for results conversion	1
The complexity of agricultural production is high, and there are many factors affecting agricultural production and efficiency and farmers' income, thus the process of agricultural S&T innovation and transformation of agricultural S&T achievements is also accompanied by the multifaceted influence of these factors.	The conversion of results is influenced by natural conditions and production methods	1
Although there are many intermediaries for results transformation, most of them do not have sufficient understanding of the market or customer needs	Lack of market research for intermediaries of results conversion	1
China's agricultural S&T achievements transformation and promotion system and related mechanisms cannot keep pace with the rapid development of modern agriculture	The transformation and promotion system of S&T achievements is backward	2
The relatively high proportion of S&T activities in research institutions and universities makes the overall research results more limited to academic factors, ignoring market demand	Scientific research results ignore market demand	5
The traditional evaluation mechanism of s S&T achievements led by government departments can hardly adapt to the urgent demand for S&T achievements of various agricultural market players under the conditions of market economy	Inadequate evaluation mechanism of scientific research results	3
The quality of farmers also needs to be improved	Low overall quality of farmers	2
Failure to achieve unified and refined management of archives	Imperfect way of managing agricultural S&T achievements	1
The government and related departments as the main achievement award mechanism in the evaluation link is the expert group review, but the market subjects are rarely involved in the evaluation	Government-led achievement evaluation mechanism lacks market subjects	1
The imbalance between supply and demand in the transformation of agricultural S&T results caused by the insufficient investment in agricultural S&T leads to its extremely low transformation rate	Insufficient funding triggers an imbalance between supply and demand for the conversion of achievements	1
The low degree of agricultural industrialization and the short industrial chain of agricultural products processing and circulation make it very difficult to promote agricultural technology in China	Low degree of industrialization affects technology promotion	1
The applicability of technology is not strong. The research and development of applicable S&T that are meaningful to land use and sustainable agricultural development cannot be carried out in response to the	Poor technical applicability	1

Example of coding content/data	Categories to which open codes belong	Frequency
urgent practical problems that arise in the process of agricultural production.		
Most researchers focus only on theoretical results indicators such as papers, publications and patents at the beginning of their projects, ignoring the effect of transforming research results into actual agricultural productivity.	Researchers ignore productivity translation	1
The unbalanced distribution of agricultural S&T among systems, regions and levels is highlighted	Uneven geographical development of agricultural S&T	1
Many institutional, operational and technical problems remain unsolved, and financial support for agriculture is insufficient, thus forming a vicious circle between low efficiency and insufficient investment in agricultural S&T development	Low benefits of agricultural S&T development	1
Agricultural extension system does not adapt to the requirements of marketization	Agricultural extension system does not adapt to market-oriented needs	4
Slow development of intermediaries and lack of supporting services for conversion of achievements	Lack of intermediaries for the conversion of achievements	1
Little access to information and weak ability to assess the improvement of innovation	Market lacks agricultural S&T information platform	3
Farmers with weak economic power cannot afford the risks and uncertainties associated with new technologies, and thus cannot afford to equip traditional agriculture with modern material technology	High input and costs affect farmers' motivation	4
The low scientific and cultural quality of rural human resources causes poor absorption, digestion and innovation ability of new technologies, which seriously restricts the effective demand of farmers for S&T	Low overall quality of rural labor constraints on the demand for S&T	1
Shortage of scientific and innovative talents and insufficient risk management ability	Inadequate risk management capabilities	1
The development of domestic regions is unbalanced, the gap between east and west is large, and some places have low utilization of resources, duplication of construction, and serious waste, and ultimately the funds invested in the transformation of agricultural research results are even less	Large domestic local gaps with little investment funds	1
Generally, it takes about 7 years for a new agricultural variety to be developed and widely promoted, but the existing financial products are mostly short-term and small working capital loans, or long-term loans for large projects, so there are almost no financial products that match the cycle of agricultural S&T innovation	The duration of financial products does not correspond to demand	1
Most financial institutions have not established a corresponding credit management system or developed personalized financial products for the characteristics of	Financial institutions lend a single variety of loans for S&T innovation	1

Example of coding content/data	Categories to which open codes belong	Frequency
agricultural S&T innovation, and the loan varieties provided are homogeneous.		
Most of the projects have to be re-applied, and the funding support is poorly sustained, which is a common problem reflected in the research	Poor sustainability of funding support	1
Large funding gap for agricultural extension	Large funding gap for agricultural extension	1
The investment intensity of agricultural research in China is 0.77%, which is much lower than the national research investment intensity of 1.7%; the government investment intensity in agricultural research is 0.65%, which is lower than the government investment intensity of 0.8%	Low proportion of investment in agricultural S&T research	8
However, unlike foreign enterprises, which are widely involved in agricultural R&D, the proportion of private enterprises in China's agricultural research investment is less than 2%, and enterprises do not have the independent R&D capability to match the industrial development.	Insufficient investment of enterprises in research	1
The investment in agricultural S&T innovation is risky, long period and slow, resulting in lower investment benefits than business and industry, and the motivation of enterprises to invest is not high	Enterprise investment enthusiasm is low	1
Although some intermediaries and S&T intermediaries already exist in society, there are very few large-scale institutions dedicated to the realization of agricultural S&T enterprises and venture capital	Lack of professional venture capital intermediaries	1
Single means of financing and insufficient capital investment	Insufficient capital investment, and single financing channel	1
The problems of unreasonable allocation of agricultural S&T resources and inefficient use of funds also seriously hinder the sustainable development of agricultural S&T	Inefficient use of funds	2
The lack of effective communication channels and long-term mechanisms between the innovation subject and the application object of the results has prevented many results from realizing their market value	Lack of communication between innovation subject and application subject	1
It is a difficult job to develop a collaborative innovation mechanism in agricultural S&T. The phenomenon of information silos in agricultural S&T has existed for a long time. Agricultural S&T supply organizations compete for projects and funds, duplicate projects, and suppress one another	Lack of a benign competition and cooperation among scientific research actors	2
Some of China's agricultural S&T institutions are relatively loose, and the structure of scientific research institution is not reasonable	Loose agricultural S&T institutions	1

Example of coding content/data	Categories to which open codes belong	Frequency
The proportion of agricultural R&D expenditure spent on basic agricultural research, advanced high technology, and basic S&T work is too low, and the accumulation and development of agricultural biological resources, natural resources, and basic data is insufficient.	Insufficient accumulation of agricultural scientific research	1
The overall level of S&T innovation in Chinese agricultural enterprises remains low, with significant gaps when compared to developed agricultural countries.	Weak capacity of enterprise's S&T innovation	7
Leading enterprises have failed to play a leading role, but have become a weakness in agricultural industry development, affecting the competitiveness of leading enterprises in the market, preventing enterprises from extending the industrial chain, and resulting in high material consumption and low output efficiency.	Lack of leading enterprises to drive the development of industrialization	1
Every year over 7,000 agricultural S&T achievements are published, but only about 40% of them are converted into real productivity, owing to a lack of breakthrough achievements and key technologies of independent innovation.	The lack of independent innovation breakthroughs and key technologies	4
At present, scientific research units affiliated with government departments still dominate in agricultural S&T innovation	Government research institutions dominate	1
It is unavoidable for government-led agricultural S&T innovation to be inefficient. At the moment, the government is the main body of agricultural technology innovation in China, and the innovation model of scientific research institutions led by the government is in place	Inefficient government-led S&T innovation	1
There is lack of independent R&D capacity	Insufficient power of independent research and development	3
Grass-roots agricultural technicians are not very active, with old knowledge and outdated ideas, they lack the willingness to continue their studies and further education	Grassroots agricultural technicians are not well motivated	1
Inadequate organizational structure and improper incentive mechanism	Inadequate incentive mechanism	1
The institutions' basic financial expenditure for personnel and operating costs is only about 30%, and there is a 2/3 shortage of scientific staff salaries and wages, making some high-level talents unstable and unable to be retained.	Lack of S&T innovation talents/brain drain	6
The quality of scientific researchers is relatively low	Low quality of research staff	1
The development of agricultural S&T is not very attractive to young people, and there is a certain degree	Lack of talent attraction	1

Example of coding content/data	Categories to which open codes belong	Frequency
of "gap" in the training of young S&T innovation talents		
The S&T innovation system is in desperate need of innovation, and the talent training model is rigid and backward	Backward talent training mode	1
In terms of management policies, there is a deviation in the orientation of how to deal with the relationship between S&T achievements and IP rights, and the authority of the S&T progress awards established at the national and provincial levels is recognized, while insufficient attention is paid to the acquired patent rights, variety rights and commercial secrets	S&T management policies do not pay much attention to IP protection	1
Inadequate regulations in the science and technology market	Inadequate market regulations	1
The formation of partnerships to promote the rapid development of venture capital is uncommon in China, owing to a lack of detailed and clear legal provisions	Lack of legal regulations for venture capital in agricultural S&T	1
Lack of systematic policies or operational regulations to guide and bring the role of various market actors in the conversion of agricultural S&T achievements	Lack of policy guidance related to the conversion of results	1
Policies are mainly aimed at agribusiness and its related policies, and there are no corresponding policies to encourage agricultural investment behavior.	Lack of policies to guide agricultural investment	1
Researchers generally believe that the object of agricultural S&T research is animals and plants, and the object of service is farmers, with long period of obtaining results, complicated related factors, poor confidentiality, and low direct economic benefits, thus ignoring the application and protection of IP rights	Researchers neglect IP application and protection	1
At the level of S&T management concept, there is a lack of IP management ideas and awareness of S&T achievements, especially the strategic management of IP rights	Lack of awareness of strategic IP management	1
However, due to a lack of special funds, none of the patents or variety rights have been rewarded or funded, which has a direct impact on the motivation of researchers to innovate as well as the protection and application of independent intellectual property rights	Lack of financial incentives for IP affects motivation	1
The protection system of agricultural IP rights is not yet perfect, and researchers do not receive the benefits of their innovations, thus weakening their incentive to innovate	Inadequate IP protection system affects research motivation	1
The majority of agricultural research projects are completed with government funding, and the resulting inventions are classified as functional inventions, with no consideration for personal interests, which, to some extent, dampens the enthusiasm of researchers to create	Unclearly defined IP rights affect the incentive to creativity	1

Example of coding content/data	Categories to which open codes belong	Frequency
Agricultural scientists, especially project leaders and discipline leaders, need to spend a lot of time and energy on running projects and competing for funds	Research projects with little funding and tight time constraints	3
The emphasis in project establishment and evaluation is on short-term results rather than long-term results; there are more common projects organized in a competitive manner and not enough autonomous and stable arrangements for research units based on the needs of the disciplines	Unreasonable assessment of scientific research projects	1
Due to the long periodicity of agricultural research work, and the national research projects are mainly based on the implementation cycle of the five-year plan of the national economy, which cannot ensure the continuity of long-period agricultural research projects	Research project cycle discontinuity	1
At present, China's agricultural research is mainly managed under a project-based management system, which is not conducive to producing significant results because the project teams are mostly "small teams" and "small workshops"	Project-based management is not conducive to producing significant results	1
The existing agricultural S&T assessment system emphasizes indicators such as papers and projects, and ignores the effect of transformation and practical application of results, resulting in a poor match between agricultural S&T results and production needs	Agricultural S&T appraisal system is unreasonable	1
The problems of unreasonable allocation of agricultural S&T resources and inefficient use of funds also seriously hinder the sustainable development of agricultural S&T	Irrational allocation of agricultural S&T resources	1
The traditional government-led mechanism for evaluating S&T achievements can hardly meet the urgent needs of various agricultural market players for S&T achievements in a market economy, and some achievements do not meet market needs	Evaluation mechanism does not meet the market’s demand	1
Most of the results are evaluated without pilot testing, and many problems occur in the process of transforming and scaling up the results or industrialization, resulting in the failure of the results or failure to achieve the intended goal	Evaluation mechanism lacks a testing component	1
For a long time, the agricultural technology extension service system's performance evaluation and standardized assessment have been neglected, and the lack of a competition mechanism in the system causes the agricultural technology extension and service work to lose vitality	The evaluation of the promotion service system is imperfect	1
Inadequate transformation of government department functions and imperfect agricultural S&T system	Inadequate government function transformation	1
Inadequate organizational structure and improper incentive mechanism	Inadequate organization	1

Axial coding: Selecting the main categories

After the above first stage of open coding process, the derived concepts and categories have simplified a large amount of primary source content, and some independent variables in the theoretical structure system have gradually emerged. However, almost all of the categories derived from the open coding stage are independent, and the relationships between them have not been explored in depth, which is a necessary prerequisite for drawing conclusions. For this reason, it is necessary to link the independent categories and reintegrate the decomposed information. Thus, the main task of axial coding is to discover and establish the various relationships between concepts in order to express the internal connections between the various parts of the data. This step of the research will further categorize the conceptual categories derived from the above open coding phase according to their intrinsic connections and then assign them to classifications (Bryant & Charmaz, 2010). The results of which are presented in the following Table 4.

Table 4: Result of axial coding

Subcategory	**Frequency**	**Main categories**	**Frequency**
Inadequate information dissemination channels for scientific research achievements	3	Conversion rate of agricultural science and technology results	22
Mismatch between scientific research results and market demand	5		
Low conversion rate of agricultural S&T results	7		
The conversion and promotion service system of scientific research results is imperfect	6		
Inadequate mechanism for international exchange and cooperation in agricultural S&T innovation	1		
Low degree of agricultural industrialization	1	Agricultural technology extension/promotion	2
Lack of agricultural S&T promotion	1		
Low capacity in agricultural S&T innovation	8	Scientific research actors	13
Interface between industry, academia and research of the innovation system is untight	1		
The primary position of enterprise research is weak	4		
Lack of risk compensation mechanism	2	Financial investment in agricultural research	15
Mismatch between financial product supply and actual demand	2		
Few financing channels for S&T innovation	1		
Inadequate allocation of agricultural basic S&T resources	1		

Subcategory	Frequency	Main categories	Frequency
Insufficient funding for agricultural S&T research	9		
Inadequate evaluation mechanism for scientific research awards	4	Talent team construction	13
Lack of scientific research talents	4		
Low comprehensive quality of agricultural subjects	5		
Policy guidance in agricultural S&T is insufficient	1	Policies and regulations	1
Weak awareness of agricultural intellectual property protection	2	Intellectual property protection	5
Inadequate incentive mechanism for agricultural intellectual property	1		
Lack of financial security for agricultural intellectual property incentives	1		
Unclearly defined agricultural intellectual property rights	1		
Innovation system construction lags behind	1	Organization and management	12
Short implementation cycle for scientific research projects	2		
Backward scientific research organization	2		
Inadequate management mechanism of agricultural research	7		

Selective coding

The process of open coding and axial coding deepens the understanding of the categories and their relationships. Selective coding, on the other hand, is still required. Selective coding is the process of identifying core categories, systematically relating them to other categories, verifying the relationships between them, and supplementing the categories where conceptualization is lacking (Glaser & Strauss, 2017). Following selective coding, a new substantive theoretical structure is developed, while the original sources are revisited to validate the relationships between them. Selective coding is essentially the selection of a core category from all the conceptual categories that have been discovered after a systematic analysis. The results of the selective coding are shown in the Table 5 below.

Table 5: Result of selective coding

Main categories	Frequency	The fundamental category
Conversion rate of agricultural science and technology results	22	Main constraints in Chinese agricultural technological innovation
Agricultural technology extension/promotion	2	

Main categories	Frequency	The fundamental category
Scientific research actors	13	
Financial investment in agricultural research	15	
Talent team construction	13	
Policies and regulations	2	
Intellectual property protection	5	
Organization and management	12	

By combining the coding categories and corresponding frequencies, the following most important factors that impede innovation in Chinese agricultural science and technology, as well as the main reasons behind those constraints, can be identified:

1) The most obvious constraint is severe lack of financial investment in agricultural research. Inadequate investment in agricultural research funds, as well as lack of financing channels, financing means, and risk replenishment mechanisms, have severely hampered agricultural science and technology innovation. The reason for this is primarily due to the low proportion of national investment in agricultural research, as well as the low efficiency of the use of invested funds, making it difficult to close the funding gap required for agricultural extension. Furthermore, agricultural science and technology venture capital is also a significant component of science and technology finance. Furthermore, agricultural science and technology venture capital is a significant component of science and technology finance. However, due to the overall low profit level of agricultural production, high risks, and an imperfect enterprise system, it is difficult for agricultural science and technology enterprises to obtain venture capital and adequate financial product support, and the market's existing financial products and financing channels usually appear monotonous and do not match demand.

2) One of major obstacles to China's agricultural science and technology innovation is the low conversion rate of agricultural science and technology results. To a large extent, the level of agricultural science and technology innovation is measured by whether science and technology can be transformed into real productivity. Many factors conduce to the low conversion rate, including natural production constraints, backward conversion and extension system, insufficient funds for extension and conversion, lack of systematic policies and operational regulations, and farmers' relatively low quality and acceptance. However, one of the main reasons is that most scientific and technological achievements do not meet market demand, making it difficult to

promote and convert; second, the mechanism for evaluating scientific research achievements is inadequate. The existing evaluation of agricultural achievements focuses primarily on aspects such as the achievements' advancedness and regional adaptability, with insufficient consideration given to operability, applicability, application prospect, comprehensive supporting, cost and benefit, and market demand, resulting in a portion of the achievements being disconnected from market demand and failing to convert.

3) One impediment that cannot be overlooked is the outdated and ineffective agricultural technology extension system. Whereas the greatest impact of technological innovation is achieved through technology diffusion and transfer, resulting in an expansion of the scale of application of technological achievements and widespread recognition of their value. Agricultural technology diffusion frequently serves as a bridge connecting the two ends of the agricultural innovation system. The reasons for the extension system's unsoundness stem primarily from two factors. First, the agricultural extension system does not adapt to marketization requirements. Currently, the majority of China's agricultural extension system is based on administrative means, and extension activities have a strong administrative flavor, resulting in a poorly functioning extension system. Second, the high risk and uncertainty associated with adopting new technology dampens farmers' eagerness to embrace advanced scientific and technological achievements. Farmers are generally afraid of taking risks due to the influence of past experience.

4) Problems of scientific research actors have also hampered the advancement of agricultural science and technology innovation. For example, the enterprise's scientific research subject's status is unclear, and the industry-university-research innovation system is not tightly linked. The root cause of the former is the enterprise's lack of innovation capability and insufficient motivation for independent research and development. The latter is due to a lack of collaborative innovation caused by absence of benign competition and cooperative communication among various research actors.

In addition to the aforementioned major constraints, the structural shortage of agricultural science and technology innovation talent, as well as the overall low quality of practitioners, is the impediment that deserves special attention. Each stage of scientific and technological advancement, from R&D to promotion to transformation, is inextricably linked to a group of top-tier talent teams. However, the brain drain is relatively severe due to poor research conditions and low treatment in agricultural research facilities. Furthermore, as the primary source of agricultural labour and beneficiaries of technological advances, farmers have been displaced in large numbers as a result of urbanization.

Farmers who remain in the agricultural system are generally uneducated, of poor quality, and have a limited ability to accept and apply scientific knowledge, limiting the promotion and application of agricultural technology.

It is worth noting that agricultural science and technology's weak intellectual property protection mechanism has, to some extent, limited agricultural technological innovation. The main issues are incomplete legislation in this field, ineffective law enforcement, and a lack of awareness among relevant practitioners about their rights.

In addition, flaws in organization and management, as well as policies and regulations, obstruct agricultural science and technology innovation. In order to create a favorable development environment for agricultural science and technology innovation, macro policies, market regulations, and intellectual property protection require correct policy guidance. At the moment, the management of agricultural science and technology in China is primarily led by the government, and the market supervision mechanism, science and technology incentives, and science and technology risk mechanisms are all ineffective, resulting in a lack of proper guidance, supervision, and management of science and technology innovation, as well as some long-term and fundamental problems, resulting in a large amount of wasted human, material, and financial resources.

These constraints are classified into three levels of Macro-(policy, institution, and system), Meso-(society, network, and market), and Micro-(farmer, firms, and workers) as follows:

Macro-level: Insufficient financial investment in agricultural research; flaws in organization and management, as well as policies and regulations; lack of mechanisms for protecting intellectual property rights in agricultural science and technology.

Meso-level: Backward agriculture technology promotion system; low conversion rate of agricultural science and technology achievements.

Micro-level: Inadequate connection between scientific research subjects.

5 Conclusion

Brief restatement of objectives and a short summary

In conclusion, this thesis conducted a qualitative analysis of 20 articles based on grounded theory in order to investigate the main problems in current agricultural science and technology innovation in

China, as well as the most likely formation causes of the problems. According to the findings of the analysis, the four most significant constraints to the advancement of agricultural science and technology innovation are as follows: 1) severe lack of financial investment in agricultural research; 2) low rate of conversion of agricultural science and technology achievements; 3) backward agricultural technology promotion and diffusion system; and 4) Inadequate innovation capacity of scientific research actors, as well as a lack of collaborative innovation between them.

It is also worth noting that these constraints are not isolated and fragmented, but rather are inextricably linked and influenced. One of the most logical chains is as follows: insufficient financial investment leads to inadequate innovation capacity of scientific research actors, which results in poor promotion of agricultural science and technology achievements, which would, in turn, causes low rate of achievement conversion.

Discussion of wide implication of research results

Based on the findings presented above, this study can provide some feasible policy recommendations for relevant policymakers in the Chinese agricultural sector to help them get out of the current bind: 1) To improve the efficiency of the use of scientific research funds, both the government and enterprises should increase the intensity of investment in agricultural scientific research, diversify investment channels, and optimize the investment structure. 2) Reform the mechanism for establishing scientific research projects, with a focus on farmer and market needs; improve the mechanism for evaluating innovation performance; and ensure the benefits of agricultural researchers during the conversion; broaden investment channels and build a service system for the conversion and promotion of scientific research achievements. 3) Reform and adjust the agricultural science and technology promotion mechanism as soon as possible; improve the agricultural diffusion system. Strengthen the development of agricultural science and technology personnel; provide education and training to farmers in order to improve their overall quality and acceptance of new technologies. 4) Strengthen the dominant role of enterprises (including the entire investment, innovation, and application process), promote the integration of industry, academia, and research, and encourage collaborative innovation among various innovation subjects.

Research shortcomings and future research directions

The study's sample size was limited due to time and energy constraints, so the study's accuracy may be limited. Furthermore, when selecting the analyzed subjects, I did not deliberately consider the impact factors of various publications, but rather chose them based on the criteria I developed. Finally,

the research methodology conducted in this thesis is qualitative, whereas quantitative analysis or related research could be used to improve the accuracy of the results in future related studies.

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